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THESIS

THE SELECTION OF A MARINE ARTILLERY
BATTERY FIRE DIRECTION COMPUTER SYSTEM

by

Paul Andrew Gido
December 1982

Co-Advisors: Dan C. Boger
Joseph F. Mullane

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As a result of the analysis, the author recommends the procurement of the Magnavox Artillery Computer System (ACS). The author further recommends that the ACS be adapted for use as a battalion level fire direction system on an interim basis until the introduction of MIFASS. Additionally, a number of recommendations which are representative of the types of action needed to assist in the resolution of the Marine artillery fire direction problem are provided.

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The Selection of a Marine Artillery Battery Fire Direction Computer System

by

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Major, United States Marine Corps
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Submitted in partial fulfillment of the
requirements for the degree of

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ABSTRACT

The artillery fire direction systems currently used by the U.S. Marine Corps are inadequate to meet the demands of today's battlefield. The lack of a modern artillery fire direction computer system degrades the Marine Corps overall combat effectiveness.

This thesis presents a cost effectiveness analysis of four fire direction computer systems which can significantly enhance an artillery battery's combat effectiveness. An application of Multi-Attribute Utility Theory is used to determine a single measure of effectiveness.

As a result of the analysis, the author recommends the procurement of the Magnavox Artillery Computer System (ACS). The author further recommends that the ACS be adapted for use as a battalion level fire direction system on an interim basis until the introduction of MIFASS. Additionally, a number of recommendations which are representative of the types of action needed to assist in the resolution of the Marine artillery fire direction problem are provided.

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I. INTRODUCTION

A. BACKGROUND

Currently a Marine Artillery Battalion/Battery has three methods for computing firing data: Manual procedures, Field Artillery Digital Automatic Computer (FADAC), and Programmable Hand-Held Calculator (PHHC). Marine artillery does not have a "standard" primary method for determining firing data. The four artillery Regiments emphasize different methods.

Manual procedures cannot provide the responsive, accurate and effective artillery fire support that is needed on today's battlefield. The FADAC is at the end of its service life. Its contribution to combat effectiveness has been degraded by continual maintenance problems. The PHHC has very limited capabilities. It cannot meet the mission processing demands of extended combat operations.

Since 1967 the Marine Corps has been involved in the development of the Marine Integrated Fire and Air Support System (MIFASS). MIFASS is designed to meet the requirements of battalion and higher headquarters. In the mid 1970's the Marine Corps realized that a requirement existed for a battery level fire direction computer system to support autonomous battery operations. The Marine Corps participated

with the Army in the development of the Battery Computer System (BCS). In 1979 the Marine Corps decided to withdraw from the BCS program. The Marine Coprs initiated a search for its own battery level fire direction computer system. The Army will commence fielding the BCS in second quarter FY 1983. The Marine Corps will conduct an operational test of the Artillery Computer System (ACS) at Camp Lejeune, North Carolina in January 1983. The ACS is being developed by Magnavox. American and foreign firms are actively marketing a number of fire direction computer systems. These systems are in various stages of design/development.

Artillery is the Marine Air Ground Task Force Commander's primary all-weather fire support asset. The lack of a modern artillery battalion/battery fire direction computer system degrades the Marine Corps overall combat effectiveness. The current fire direction systems are inadequate to meet the demands of today's battlefield. MIFASS is at least five years over the horizon. The Marine Corps faces a critical window of vulnerability at the artillery battalion level until MIFASS or a derivative of MIFASS is fielded. However, MIFASS will not resolve the fire direction problem at the battery level.

In April 1982, The Report of the MIFASS Program Review stated that the fire direction problem is especially critical at the battery level and needs to be expeditously resolved. The artillery battery needs an automated computational capability to support autonomous operations.

B. OBJECTIVE AND SCOPE

The objective of this thesis is to determine which battery level fire direction computer system the Marine Corps should procure. This thesis assumes that MIFASS or a derivative of MIFASS is the long range solution for the artillery battalion fire direction problem.

This thesis assess the current status of fire direction in Marine artillery units and provides a cost effectiveness analysis of four proposed battery level fire direction computer systems. Active and Reserve Marine artillery units are addressed in this thesis. It was beyond the scope of this thesis to evaluate all the currently available fire direction computer systems. Preliminary analysis was used to narrow the list of possible alternatives to the primary candidates for replacing the current Marine Corps fire direction systems. It should be noted that a number of other fire direction computer systems exist.

Life cycle cost data have been estimated for only one of the alternatives considered in this thesis. It was beyond the capabilities of this author to develop accurate estimates of life cycle cost for the other three alternatives in the short time span available for the preparation of this thesis. It is recognized that life cycle cost data provide the best measure of system cost for a cost effectiveness analysis. Since these data were neither available nor could they be accurately estimated, procurement cost was used as a proxy to measure the system cost.

It is intended that this thesis will provide the general background and analysis for decision makers who have not been directly involved in the development of the various fire direction systems. The analysis provides step by step procedures, so that the decision maker can input new data and quickly revaluate the alternatives. It is intended that this thesis will assist in the expeditous resolution of the fire direction problem at the artillery battery level.

C. METHODOLOGY

In order to factually determine the current status of fire direction in Marine artillery units, questionnaires were sent to all Marine artillery commanders in the current force structure (active and reserve). Extensive research of existing documentation was conducted in order to provide a historical perspective on the development of fire direction systems. This author visited the manufacturers of the four alternatives that this thesis considers. Data and information were collected through numerous personal interviews of manufacturers' representatives, artillery commanders, and officers and non-commissioned officers involved in the development of fire direction computer systems. Additional data were derived from personal observation of the four alternative systems and from an analysis of their technical descriptions.

D. SUMMARY OF CHAPTERS

The second chapter of this thesis provides an overview of the mission and organization of Marine artillery, a brief discussion of the fundamentals of gunnery and an explanation of tactical and technical fire direction. Chapter III reviews the development of fire direction systems. It provides the historical perspective for the problem that this thesis addresses. Chapter IV presents the current status of fire direction in Marine artillery units. It presents separately the responses to the questionnaires from the different levels of command, and then summarizes the input from all levels of command to provide a general view of the status quo. Chapter V provides the technical descriptions of the four alternatives. Each alternative is discussed separately, and then the major characteristics of all the alternatives are summarized in one table. Chapter VI provides the cost effectiveness analysis of the four alternatives. A benefit-cost approach is used to determine the optimal solution. Chapter VII provides the conclusions of this thesis and offers recommendations derived from the analysis.

II. AN OVERVIEW OF MARINE ARTILLERY

A. INTRODUCTION

Today's battlefield is characterized by the application of advanced technology, mobility of maneuver units over wide frontages, employment of massed firepower and increased lethality. Recent battlefield experience in the Falklands and the Middle East has once again demonstrated the value of the combined arms team. The rapid movement of maneuver units closely supported by air, artillery and naval gunfire has proved to be the decisive factor.

The realizations that close air support aircraft are increasingly vulnerable to frontline air defenses and that current naval gunfire support assets are inadequate have generated a renewed recognition of the importance of field artillery. Marine artillery units provide around-the-clock, quick reaction, all weather fire support for maneuver units. The ability to quickly mass artillery firepower at the critical point is essential for success on the battlefield. Fire direction is the employment of artillery firepower. It consists of both tactical and technical fire direction. The fire direction center (FDC) is the element of the Gunnery Team with which the commander directs the application of firepower. This chapter will provide: an overview of the

mission and organization of Marine artillery, a brief discussion of the fundamentals of gunnery and an explanation of tactical and technical fire direction.

B. MISSION

Fleet Marine Force Manual 7-4 (FMFM 7-4), Field Artillery Support, contains the fundamental framework and guidance for Marine artillery. It addresses the mission, organization and concept of employment for artillery units. Marine artillery has the following general missions in support of amphibious assault and subsequent operations ashore:

1. Providing fire in support of maneuver actions and as part of the overall fire support effort to include:

   a. Providing close and continuous fire support to elements of landing force by destroying, neutralizing or suppressing those targets which constitute a threat to the supported unit.

   b. Conducting counterfire operations against enemy indirect fire systems in order to achieve and maintain fire superiority over these systems.

   c. Giving depth to combat by attacking the enemy's reserves, restricting movement, providing long range support for reconnaissance elements, and disrupting the enemy's command and control structure and logistics system.

2. Providing fire support planning and coordination resources and facilities to all levels of command.

C. ORGANIZATION

1. Current Organization

The organizational structure of Marine artillery has three levels of command: regiment, battalion and battery. The structure of a Marine division provides an artillery regiment as its principal source of fire support. "The artillery regiment is organized administratively to support the operations of the division with components capable of supporting infantry regiments and their battalions." [Ref. 1: p. 1-4] The artillery regiment consists of a headquarters element (Headquarters Battery) and a specified number of battalions. Each battalion consists of a Headquarters Battery and a specified number of firing batteries.

The United States Marine Corps has three active artillery regiments and one reserve artillery regiment. The administrative organization of artillery units is established in the appropriate Table of Organization (T/O). Appendix B graphically presents the current organization of the four artillery regiments. Each artillery regiment is organized differently.

These differences in structure originated in the reorganizations of Marine artillery following the drawdown of forces at the conclusion of the war in Vietnam. The active force structure of Marine artillery was significantly

reduced in the years following Vietnam. The current organization of Marine artillery evolved from the allocation of active artillery units to support the primary mission of each Marine division. The artillery regiments were structured to counter the particular threat that each Marine division faced. The introduction of the M198 (a 155mm Towed Howitzer) and the phasing out of the M107 (a 175mm Self Propelled Gun) has created additional differences in the organization.

2. The FY 1987 Projected Force Structure

Marine artillery is in the midst of a large scale reorganization. "The reorganization will evolve over a period of years with a projected completion date of the end of FY 1987" [Ref. 2: p. 11]. When this reorganization is completed all four artillery regiments will have the same basic organization. Figure 2.1 depicts the FY 1987 projected force structure of the three active artillery regiments. This thesis will address the FY 1987 projected force structure. The evolutionary steps to reach this structure will not be addressed. Each active artillery regiment will consist of a Headquarters Battery, Target Acquisition Battery, and five artillery battalions (three direct support battalions and two general support battalions).

Control of artillery in combat is exercised not only through the organizational command relationships, but also

ARTILLERY STRUCTURE - END OF FY 87

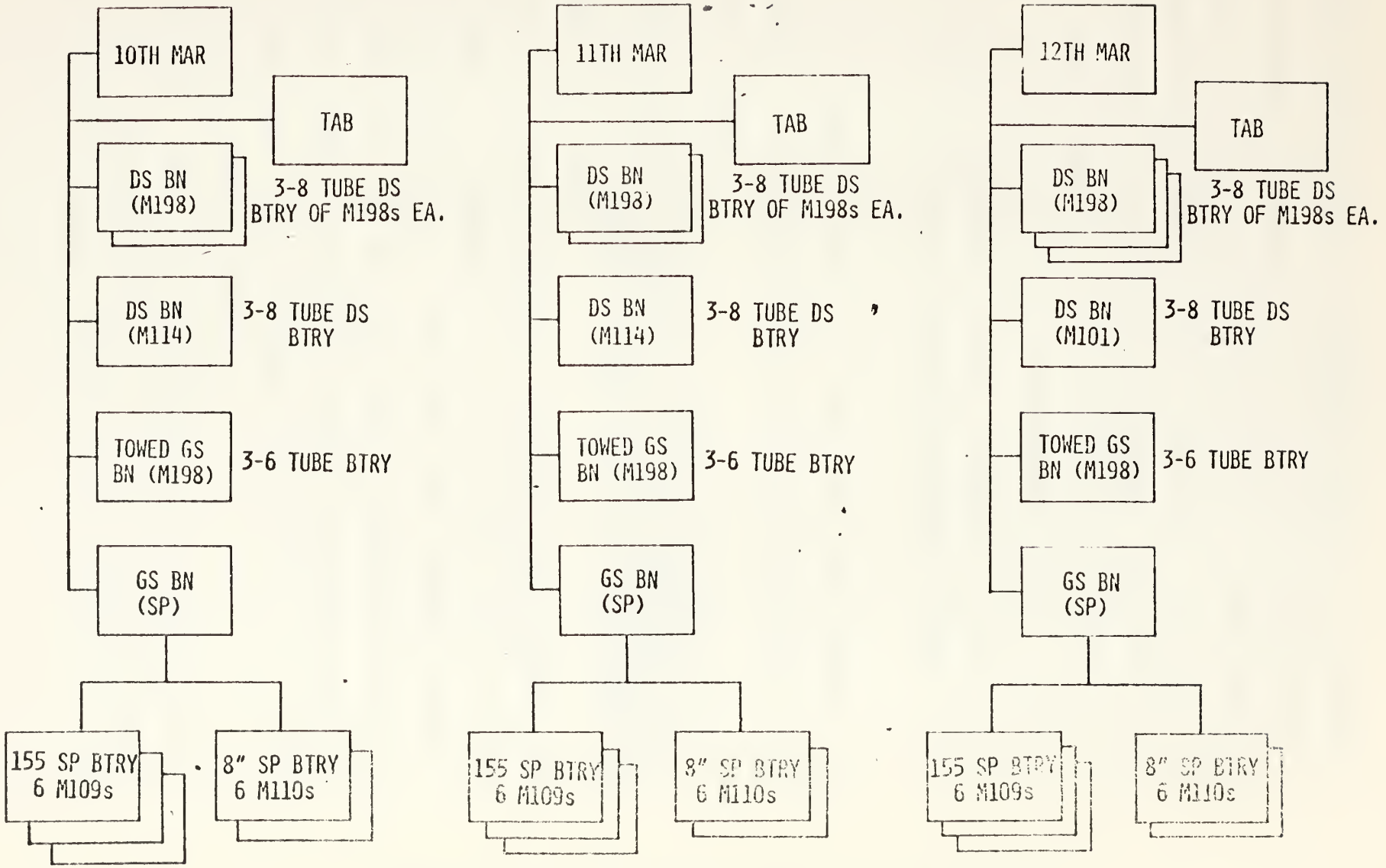


Figure 2.1 FY 1987 Projected Force Structure

through the assignment of a tactical mission. A tactical mission describes in detail the fire support responsibilities assigned to an artillery unit. The tactical mission prescribes the fire support tasks of the unit, outlines the responsibilities of the artillery commander, and establishes the fire request channels. In organizing for combat operations an artillery battalion is assigned one of the four standard tactical missions: direct support, reinforcing, general support or general support-reinforcing. [Ref. 3: p. B-6]

An artillery battalion assigned the mission of direct support is responsible for providing fire support for an infantry regiment.

> The mission of direct support requires the artillery unit to assign forward observers to, and establish close liaison with, the supported unit and to plan and deliver fires in direct response to the needs of that supported unit [Ref. 2: p. 50].

An artillery battalion assigned the mission of general support is responsible for providing fire support for the force as a whole. The fires of a general support unit are controlled by the next higher artillery headquarters. General support battalions provide the force commander with an immediately available source of firepower with which to influence the course of battle.

The 1st, 2d, and 3d Battalions of each artillery regiment have been configured to meet the requirements of the direct support mission. The 4th and 5th Battalions have

been configured to meet the requirements of the general support, reinforcing, and general support-reinforcing missions. Marine artillery battalions are identified as either direct support or general support battalions.

Currently, except for the 10th Marines, a direct support battalion consists of a Headquarters Battery and four firing batteries. (See Appendix B.) Three of the firing batteries are equipped with the M101A1 (a 105mm Towed Howitzer). The fourth battery is equipped with the M114A2 (a 155mm Towed Howitzer). All of the batteries have six howitzers. Therefore a battalion has a total of twenty-four howitzers (18 M101A1s and 6 M114A2s).

The projected force structure changes the composition of the direct support battalions. (See Figure 2.1.) Each direct support battalion will consist of a Headquarters Battery and three firing batteries. Each firing battery will be equipped with eight howitzers. In the artilleryman's vernacular this is referred to as the "3 X 8" concept. The "3 X 8" structure only applies to the direct support battalions.

Two of the three direct support battalions in each regiment will be equipped with M198s. The third direct support battalion in the 10th and 11th Marines will be equipped with M114A2s. The third direct support battalion in the 12th Marines will be equipped with M101A1s. As a result of the introduction of the M198 and the reorganization of

artillery assets, the 155mm will replace the 105mm as the "standard caliber" for direct support battalions.

The projected force structure also changes the composition of the general support artillery battalions. (See Figure 2.1.) The 4th Battalion in each regiment will be a towed general support battalion. It will consist of a Headquarters Battery and three firing batteries. Each firing battery will be equipped with six M198s. The 5th Battalion in each regiment will be a self propelled battalion. It will consist of a Headquarters Battery and five firing batteries. Three of the firing batteries will be equipped with six M109A3s (a 155mm Self Propelled Howitzer). The two remaining firing batteries will be equipped with six M110A2s (an 8 inch Self Propelled Howitzer).

3. Impact of the Reorganization

The reorganization of Marine artillery will have a tremendous impact on fire support. The adoption of the 155mm as the standard caliber will produce a significant increase in overall fire power. The 155mm has a more extensive ammunition mix than the 105mm. Included in this mix are dual purpose improved conventional munitions (DPICM) and the family of scatterable mines (FASCAM). FASCAM projectiles are of two types: the area denial artillery munition (ADAM) and the remotely activated antitank mine (RAAM). These types of munitions were not developed for the 105mm howitzer. The

employment of DPICM and FASCAM will dramatically increase the lethality of Marine artillery on the battlefield.

However, this more extensive ammunition mix will significantly increase the computational requirements of the artillery battery fire direction centers. The computations needed to determine firing data for these new types of munitions are complicated. Generally speaking, the solution of the gunnery problem for the 155mm is more complex than the 105mm. The 155mmm has two basic types of propellant and a larger selection of projectiles and fuzes to chose from. The 155mm has a greater range capability. Small errors in computation are magnified as the range increases.

The complexity of the fire control procedures for the employment of the new family of munitions, against the highly mobile targets on today's battlefield, requires automated assistance in order to provide fire support that is responsive and accurate. The fire control problem is greatest at the battery level and should be resolved as soon as possible. [Ref. 4: p. iv]

The introduction of the "3 X 8" concept in the direct support artillery battalions creates many additional problems. A partial list of these problems includes: development of a new organizational structure for the battery, adoption of new Tables of Organization to support this structure, changes in field artillery doctrine and concept of employment, and the adoption of fire direction procedures

which will complement the structure. Any one of these problems could be the subject of a separate thesis. This thesis addresses the FY 1987 projected force structure depicted in Figure 2.1. It will specifically consider the impact of the "3 X 8" concept in the selection of a new battery level computer system.

D. FUNDAMENTALS OF GUNNERY

1. The Gunnery Problem

Field artillery weapon systems can engage targets at extended ranges. Normally, they are emplaced in defilade positions to provide concealment from enemy target acquisition systems and protection from enemy direct fire weapons. Their position on the battlefield usually precludes sighting the weapons directly at the target (direct fire). For the vast majority of targets indirect fire must be employed. "The gunnery problem is to determine aiming and ammunition data that ensures timely, accurate and effective indirect fire." [Ref. 5: p. 1-2]

The solution of the gunnery problem provides weapon and ammunition sightings that cause a projectile to burst on target or at a predetermined height of burst above the target. There are four basic steps involved in the solution of the gunnery problem:

a. Know the location of the weapon and determine the location of the target.

b. Determination of chart data (direction, range, and vertical interval from weapon to the target).

c. Conversion of chart data to firing data. Firing data includes: fuze setting, deflection and quadrant.

d. Application of the firing data to the weapon and ammunition.

Standardization of gunnery techniques is accomplished utilizing appropriate U.S. Army Field Manuals of the field artillery series (FM 6-). These manuals are approved for use by Marine Corps artillery units and are applicable with only minor modifications necessary as a result of differences in organization and equipment. [Ref. 1: p. 3-2]

The solution of the gunnery problem is achieved through the coordinated efforts of the field artillery Gunnery Team.

2. The Field Artillery Gunnery Team

The field artillery Gunnery Team consists of the forward observer (FO), the fire direction center (FDC) and the firing battery linked by an adequate communications network. Field artillery doctrine requires that the elements of the Gunnery Team operate with a sense of urgency and continually strive to minimize the total time needed to execute an effective fire mission. [Ref. 6: p. 1-2] Responsive fire support is critical on today's battlefield.

a. Forward Observer

The Forward Observer is the eyes of an indirect fire system. He detects and locates suitable targets for indirect fire systems within his zone of observation. To engage a target, he transmits a Call-For-Fire to the FDC and

when necessary adjusts the fires onto the target. The FO is responsible for providing surveillance data on all fires delivered in his zone of observation.

b. Fire Direction Center

> The artillery FDC is that element of the artillery command post (CP) that consists of operations, intelligence and the necessary communications personnel and equipment by which the artillery commander directs artillery fire [Ref. 1: p. 3-5].

The FDC utilizes information contained in the FO's Call-For-Fire to determine firing data. The FDC transmits the firing data in the form of fire commands to the howitzer sections. "The FDC serves as the brain of the artillery system." [Ref. 5: p. 1-3]

c. Firing Battery

The firing battery consists of a firing battery headquarters and the howitzer sections. In the context of the gunnery team, the term firing battery refers to the howitzer sections. They apply the firing data to the weapons, load the specified ammunition and fire the weapon. "The firing battery serves as the brawn of the artillery system." [Ref. 5: p. 1-3]

E. FIRE DIRECTION

Fire direction is the employment of artillery firepower on the battlefield. It involves the application, control and coordination of artillery fire support.

> The objectives of fire direction are to provide continuous, accurate and responsive fire support under all conditions, to maintain flexibility to engage all types of targets over wide frontages, to mass the fires of all available units quickly, and to engage a number and variety of targets simultaneously [Ref. 5: p. 2-1].

Fire direction consists of two distinct subelements; tactical fire direction and technical fire direction. FMFM 7-4 and the U.S. Army Field Manual (FM) 6-40, Field Artillery Gunnery, both define fire direction and its subelements in essentially the same manner. FM 6-40 (p. 2-1) defines the two as follows:

> Tactical fire direction is the command of one or more units in the selection of targets to attack, the choice of the unit or units to fire, and the allocation of the most suitable ammunition for each mission.
>
> Technical fire direction is the conversion of calls for fire from the observer into fire commands to the cannon sections.

Since this thesis is concerned with evaluating computer systems which will enhance technical fire direction at the battery level, understanding the difference between tactical and technical fire direction is critical. The main difference is, "that tactical fire direction involves command, whereas technical fire direction is concerned only with execution". [Ref. 7: p. 59] Technical fire direction is the computational process which determines firing data.

Tactical fire direction is exercised by FDC's at all echelons of command. It is the only type of fire direction exercised by the artillery regiment's FDC. Technical fire

direction is exercised by those FDC's which directly control firing units; that is, battalion and battery FDCs. [Ref. 1: p. 3-3]

1. Control of Fire Direction

The control of fire direction may be centralized or decentralized. Current doctrine emphasizes the centralization of tactical fire direction at the battalion FDC in order to provide a rapid means for massing fires, and the decentralization of technical fire direction to the battery FDCs. The centralization/decentralization of technical fire direction has been a very controversial issue among Marine artillerymen.

There was a large inconsistency regarding the centralization/decentralization of technical fire direction between FMFM 7-4 and FM 6-40 which fueled the controversy. The current FMFM 7-4 (dated 1981) eliminated a large part of the inconsistency. Both manuals emphasize that the decentralization of technical fire direction is the preferred method. FMFM 7-4 states that,

> the commanding officer designates the echelon which will exercise primary technical fire direction responsibility. In this regard, decentralized technical fire direction at the battery level is preferred because it is more responsive. (Emphasis added is mine.)

The control of technical fire direction (centralized/decentralized) has a large impact on the design requirements for a fire direction computer. Although current

doctrine emphasizes decentralization of technical fire direction, it gives the commander the option of centralized technical fire direction at the battalion FDC, if the situation dictates. According to doctrine, a battery FDC is responsible for exercising decentralized technical fire direction. The battery must have the capability to determine firing data for its howitzer sections. A battery FDC is not responsible for the concept of centralized technical fire direction. The responsibility for centralized technical fire direction clearly lies with the battalion FDC. The design requirements for a new battery fire direction computer should be based on current doctrine. The firing battery needs a fire direction computer which computes firing data for its howitzer sections. A fire direction computer which has the additional capability of centralized technical fire direction is in reality a battalion fire direction computer.

This chapter has provided a general overview of Marine artillery. It has discussed the mission and organization of Marine artillery, the fundamentals of gunnery and fire direction. The next chapter traces the development of fire direction systems.

III. DEVELOPMENT OF FIRE DIRECTION SYSTEMS

A. INTRODUCTION

In Chapter Two, technical fire direction was defined as the conversion of Calls-For-Fire from the observer into firing data which is transmitted to the howitzer sections. Currently a Marine artillery battalion/battery has three methods for computing firing data: Manual procedures, Field Artillery Digital Automatic Computer (FADAC) and Programmable Hand-Held Calculator (PHHC). Additionally, since 1967 the Marine Corps has been involved in the development of the Marine Integrated Fire and Air Support System (MIFASS). MIFASS is designed for battalions and higher headquarters. It will perform tactical and technical fire direction for artillery units.

In 1980 the United States Army began fielding a Tactical Fire Direction System (TACFIRE). This system was also designed for battalions and higher headquarters. Due to the on-going development of MIFASS, the Marine Corps did not procure TACFIRE.

The Army and the Marine Corps recognized the requirement for a new battery level fire direction computer to replace FADAC. They jointly pursued the development of the Battery Computer System (BCS). In 1979 the Marine Corps decided not

to procure the BCS. The Marine Corps initiated a search for its own battery level fire direction computer. The Army will begin fielding the BCS in the second quarter of FY 1983. The Marine Corps has scheduled an operational test for the Artillery Computer System (ACS) for January 1983.

This chapter will review the development of fire direction systems. It provides the historical perspective for the problem that the thesis addresses.

B. MANUAL FIRE DIRECTION SYSTEM

The manual fire direction system has evolved from the systems used in World War II, Korea and Vietnam. The Manual System uses graphical equipment to determine firng data. Although this equipment has been improved over the past forty years, it still retains much of its original form. The graphical equipment consists of a firing chart, range deflection protractor (RDP), graphical firing tables (GFTs, basically a slide rule) and tabular firing tables (TFTs).

A brief discussion of the manual procedures used in a battery FDC is provided. When a Call-For-Fire is received by the FDC, the target location is manually plotted on grided firing charts by the horizontal control operator (HCO) and the vertical control operator (VCO). The battery fire direction officer (FDO) analyzes the request for fire and issues a fire order to the FDC. The HCO determines a chart range (distance from the battery to the target) and a chart

deflection (direction from the battery to the target). The VCO determines chart data as a "check" on the HCO. The VCO then determines the vertical interval (VI, difference in altitude between the battery and the target). The computer places the range on the appropriate GFT and determines the elevation. The computer applies a total deflection correction to the chart deflection to determine the deflection to fire. The computer uses the VI to determine site (a correction factor for VI). The site is applied to the elevation and the quadrant evelation to fire is determined. As the firing data is being determined, the computer transmits fire commands to the howitzer sections. The entire process is supervised by the battery operations chief and the FDO. [Ref. 5: pp. 2.1-2.22]

In 1976, following the war in the Middle East, the United States Army Field Artillery School (USAFAS) began to emphasize the need for responsiveness. Manual FDC procedures were streamlined to improve system response time. This was accomplished by the introduction of an improved Call-For-Fire format, fire order/fire command standards, average site maps and ballistics fan (an RDP with ballistic scales). These changes were successfully incorporated into the Manual System and are in use today.

The number of personnel assigned to the battalion/battery FDC is established by the appropriate T/O. The current Marine Corps T/Cs are based on the number of personnel required for manual mission processing.

C. FIELD ARTILLERY DIGITAL AUTOMATIC COMPUTER (FADAC)

In the mid 1950 's the United States Army realized that artillery fire support could be significantly improved, if the time consuming and repetitive manual fire direction procedures could be automated. FADAC (M18 Gun Direction Computer), developed by Magnavox and fielded in the mid 1960's, was the first attempt to automate the computation of firing data. System design was based on late 1950's computer technology. FADAC was designed as a battalion/battery fire direction computer. It can only perform technical fire direction. FADAC has the capability to mass the fires of five firing batteries. It can support the concept of centralized or decentralized technical fire direction. FADAC requires a large amount of manual interaction and by today's standards has a very slow computational speed.

FADAC is a transitorized, stored-program, general purpose, digital computer designed primarily to compute firing data for a variety of artillery weapons. In addition to the cannon artillery application, programs have been developed for survey operations, sound and flash, and the Lance missile. [Ref. 8: p. 1-2]

FADAC consists of five basic elements: an input unit, storage unit, arithmetic unit, output unit and control unit. The FADAC weighs 230 pounds and is issued with a metal field table which weighs 58 pounds. The field table provides a level support for FADAC and serves as a power distribution

terminal for FADAC and its related equipment. FADAC is powered by a three KW, 120/280 volt, 400-HZ, three phase, four wire generator. Two generators are authorized to support each FADAC.

FADAC programs (punched tape) must be loaded by a Signal Data Reproducer (SDR, AN/GSQ-64). In the Marine Corps the SDR was usually located at the Regimental Headquarters. FADAC's non volatile memory retains the program once it is loaded. FADAC has built-in self-test circuits. As part of the "prepare for action" sequence the operator performs program tests to ensure that FADAC contains the proper program, that the program is working correctly and that the nixie tube filaments operate properly.

In the fire control application, the computer facilitates ballistic trajectory computation by simulation of the flight of a projectile from the tube through a known nonstandard atmosphere to impact. FADAC solves the ballistic trajectory by a process of numerical integration. It uses the modified point mass equations of motion and input data consisting of muzzle velocity, projectile weight, propellant temperature and meteorological information to account for the effects of drag, gravity and rotation in determing the firing data solution. [Ref. 9: p. 1-9] This solution is then displayed for the operator in the nixie display tubes.

FADAC represented a significant technological milestone for the field artillery. However, the actual assimilation of FADAC into the artillery proved to be very difficult. In retrospect the implementation plan for FADAC was poorly structured. In both the Army and Marine Corps there was a tremendous amount of resistence to make the change from the Manual System to FADAC. The degree of institutional resistance to change was not fully anticipated by the development community.

Many commanders in the field did not really emphasize the use of FADAC. They were well versed in the proven manual procedures and simply did not trust the FADAC solution. [Ref. 10] AS a result many FDCs used both the FADAC and the Manual System. "The problem is that we have tried to work with two computational systems (manual and FADAC) ever since FADAC was introduced." [Ref. 11: p. 61] The Manual System was used to "check" (verify) the FADAC solution. The artillery community tried to make the more advanced computer solution agree with the graphical solution. They failed to understand that FADAC could account for more of the nonstandard conditions (Projectile Weight, Propellant Temperature, Meteorological Data, Muzzle Velocity, and Rotation). [Ref. 12: p. 62]

The war in Vietnam also impacted on the general acceptance of FADAC by the artillery community. At that time there was a shortage of trained FADAC operators, supervisors

and maintenance personnel. Additionally, harsh climatic conditions (high humidity and temperature) created many unanticipated maintenance problems. The logistical base had difficulty in meeting the very high demand for maintenance support and repair parts. As a result of these factors many commanders relied on the proven Manual System.

Despite all these problems, FADAC was a significant advancement. FADAC demonstrated that it was possible to apply advanced computer technology to the field artillery system. It is the forerunner of all the automated artillery fire direction systems.

By the mid 1960's the field artillery research and development community had become convinced that the automation of fire direction procedures was absolutely necessary in order to provide responsive fire support on the modern battlefield. These forward-looking thinkers wanted to capitalize on the quantum leap in computer technology that occurred during the 1960's. The Army and the Marine Corps wanted an artillery computer system that could perform tactical and technical fire direction.

The Army began the development of the Tactical Fire Direction System (TACFIRE) as the follow-on replacement for FADAC. The Marine Corps closely monitored the development of TACFIRE. [Ref. 13: p. 3-18] However, the Marine Corps decided that what was really needed was a system which performed fire support coordination as well as fire

direction. The Marine Corps wanted an automated system for coordinating and controlling air, artillery, mortars and naval gunfire. In 1966 the Marine Integrated Fire and Air Support System (MIFASS) was conceptually defined by the Stanford Research Institute. [Ref. 14: p. 9] The Army and the Marine Corps began to proceed down two different paths. FADAC had provided the common starting point for these new systems.

D. FADAC MANUAL INTEGRATION

Over the past twenty years FADAC software (program tape) has been continually revised as new weapons and ammunition entered the inventory. Throughout the 1970's FADAC was, according to doctrine, the primary method used to compute firing data. In reality field artillery units continued to use the Manual System as the primary method. Units cited maintenance problems with the FADAC generators, poor repair parts support, lack of trained operators, a high noise level in the FDC, and mistrust of the FADAC solution as reasons for not using FADAC. [Ref. 10]

The lessons learned from the 1973 Arab Israeli War reverberated throughout the field artillery community. If artillery support was to be effective on the battlefield it had to be responsive. The Field Artillery School was directed to evaluate fire direction and determine ways to increase overall responsiveness.

In 1977 the concept of fully integrating FADAC and manual procedures was developed. The idea was to capitalize on the strengths of both systems in order to minimize individual weaknesses. FADAC's main strengths were computational accuracy and capability to quickly determine corrections for adjusting rounds. FADAC's two major weakness were slow computational speed for initial round data (approximately 2/3 Time of Flight) and extensive manual interaction. Time of Flight is based on the range to the target, type of trajectory and the charge fired.

The Manual System could usually determine data for the initial round faster than FADAC. This was especially true at extended ranges. The Manual System's response time was improved with the introduction of the Ballistic fan and other streamlined FDC procedures. These were previously discussed. (See Section B) In the FADAC-Manual Integrated FDC, manual procedures would provide firing data for the first round and FADAC would provide data for the subsequent rounds. Sucess of the FADAC-Manual Integration depends on an initial chart verification as part of the preparation for action steps and the use of FADAC derived GFT settings.

In 1977 there was a marked change in philosophy. The artillery community recognized the computational accuracy of FADAC. The current FM 6-40 (p. 4-27) states, "in all cases FADAC is more accurate". Artillerymen now looked at how they could make the graphical solution agree with FADAC. Manual

backup techniques were developed for periods when FADAC became nonoperational. These techniques allow the transfer of a fire mission to manual procedures without a significant loss in speed or accuracy.

The use of FADAC-Manual Integrated procedures is known as the "Fastest Method". The Fastest Method is based on decentralized technical fire direction. It took the artillery community over fifteen years to fully integrate FADAC into the fire direction system.

> Thus, while the Army has made some progress in integrating FADAC into its technical fire direction operations since the mid 1970's, the Marine Corps has drifted into a situation where some units use FADAC with one software program (Revision 4), some use it with another (Revision 5 or 5A), and still others don't use it at all- either because FADAC is too much trouble to maintain or because they feel more comfortable with the manual solution [Ref. 11: p. 61].

In this author's opinion, the majority of Marine artillery batteries have not achieved, nor will they ever achieve, the full potential of the integrated FADAC-Manual system. This opinion is based on actual experience, interviews and research for the thesis. It is interesting to note that some battalions/batteries still regard the Manual System as the primary source of firing data.

E. PROGRAMMABLE HAND-HELD CLACULATOR (PHHC), TI-59

The emphasis on responsiveness spurred the artillery research and development community to evaluate the possible adaption of a commercially available Programmable Hand-Held Calculator (PHHC) as a fire direction computer.

> Extensive evaluations of the hand-held calculator's potential with magnetic card programs were conducted by the United States Army Field Artillery School (USAFAS) and the United States Army Field Artillery Board in 1977. The results were encouraging, but the fragile nature of the magnetic cards and the unpredictable reliability of the card reader limited the HHC's field application. At the same time, however, the computer industry had introduced programmable modules with sufficient memory capacity for comprehensive applications without reliance on magnetic cards. [Ref. 15: p.8]

Preprogrammed memory modules were the key technological advancement in the adaption of a commercially available calculator.

The development of a PHHC received additional impetus when the U.S. Army Armament Material Readiness Command indicated, "that the capability to logistically support FADAC in the 1980's would be doubtful". [Ref. 15: p.8]

The development of TACFIRE was behind schedule. Since TACFIRE did not extend down to the battery level, the Army had decided to develop a Battery Computer system (BCS). BCS was being developed as an extension of the TACFIRE system. The development of BCS was also behind schedule due to serious software problems. If FADAC logistics support failed before the fielding of TACFIRE and BCS, Army field artillery battalions/batteries would have to rely strictly on manual fire direction procedures. To preclude this possibility an accelerated development/procurement program for the PHHC was initiated.

The PHHC was never intended to be a replacement for FADAC.

> It supplements the existing FADAC-Manual fire direction system, by simplifying gunnery computational procedures. During periods of FADAC nonavailability/inoperability (movement, lone gun operations, hip shoots), the calculator can provide the primary source of firing data. It also expedites and simplifies HB/MPI registration procedures and concurrent/subsequent Met application. [Ref. 16: p. 1-A]

The PHHC was intended to be an "FDC tool" for increasing overall responsiveness. It does not have the capabilities of FADAC (mass fire, nonvolatile memory, target storage capacity, shell fuze flexibility, 6400 mil accuracy).

The PHHC is a commercially available Texas Instrument Model 59 (TI-59), militarily adapted for cannon gunnery application by incorporating preprogrammed memory modules. It is powered by an internal rechargeable battery pack. Chargers and adapters for external power sources (AN/PRC 77 radio battery (BA4386) and 12 volt vehicle battery) are provided to extend the battery pack's life and prolong operations time. The PHHC's keyboard allows for data entry, control of calculator function, and provides for numeric display of ten digits. Two programmed modules (chips) are required to accomplish all field artillery gunnery applications. A unique weapon system chip provides firing data. The special situation chip is common to all artillery weapon systems. It contains Meteorological mathematics, Terrain Gun Position Corrections and Special Corrections, Joint Munitions Effects Manual/Surface to Surface estimates, Linear interpolation, 14.5 gunnery and Rocket Assisted Projectile (RAP) gunnery for M114A2/M109A1.

The gunnery solution computed by the PHHC is a tabular firing table (TFT) standard condition solution. The Ballistics Research Laboratory, Aberdeen Proving Grounds, Maryland produced the curve fit equations using second dergee polynomials, to fit TFT data by the least squares method. The curve fit solution is an approximation which normally agrees with the TFT solution but may vary as much as 3 mils in elevation, 1 mil drift and 0.1 second fuze setting. These accuracy requirements are met only within certain range intervals for each propelling charge, called curve fit intervals. In the determination of site, the PHHC only applies angle of site. [Ref. 15: p. 7-A]

> Although the calculator's solution is not as technically correct as the ballistic solution provided by FADAC, TACFIRE or BCS, it is more accurate than the manual solution. Unlike FADAC, the PHHC cannot automatically compensate for nonstandard conditions. [Ref. 15: p. 11]

Registration Corrections can be determined and stored in the PHHC.

The PHHC was fielded by the Army in 1980. The Marine Corps purchased 338 PHHC sets [Ref. 11: p. 61]. Because of the PHHC's limited capabilities, it could not serve as a replacement for FADAC, but it does contribute substantially to the effectiveness and versatility of the battery fire direction center. The PHHC's greatest application is at the battery level. "The calculator neatly complements the weaknesses of manual and FADAC systems, but has weaknesses of its own that are well covered by the current system."

[Ref. 17; p. 24] Its major limitations are the inability to mass fires, limited storage and memory capacity, and volatile memory.

The acquisition of the PHHC did demonstrate that an off-the-shelf item could be quickly adapted for military application in response to an urgent requirement. The PHHC is a low cost alternative method of computation with "acceptable accuracy degradation". The FY1982 cost of the PHHC computer set was $310.00 and the cost of the individual memory modules was $46.00. [Ref. 18: p. 21] The PHHC is being utilized by Marine artillery units.

F. MARINE INTEGRATED FIRE AND AIR SUPPORT SYSTEM (MIFASS)

> MIFASS will consist of staff organization and standard operating procedures assisted by a real-time display and information processing system that is designed to more efficiently employ supporting arms at the division, regiment and battalion echelons of the Marine Air Ground Task Force (MAGTF) [Ref. 19: p. 1].

Simply stated MIFASS automates the processing of all fire support requests (mortars, artillery, naval gunfire and air). It is an automated system which incorporates the latest technological advances in information processing and display equipment for coordinating and controlling supporting arms' fires.

MIFASS integrates the tasks and functions of the Fire Support Coordination Center (FSCC), the Direct Air Support Center (DASC) and some functions of the artillery's Fire

Direction Center (FDC). MIFASS is expected to facilitate decision making at battalion and higher headquarters. The ultimate goal of MIFASS is to improve the mission response time of all fire support systems. An Initial Operating Capability (IOC) for MIFASS is currently projected for CY 1987 [Ref. 4: p. vi].

MIFASS originated in 1966 when it was conceptually defined by the Stanford Research Institute in the final report on the Marine Tactical Command and Control Study (MTACCS). The MTACCS concept evolved from studies conducted in 1965-66 to determine the feasibility and practicality of applying new technology to command and control of Marine combat forces. [Ref. 14: p. 9]

> The concept envisioned a family of functionally oriented systems, bound together by commonality of equipment, operational procedures, and data bases, and operating as necessary through a common communications system [Ref. 20: p. 1].

The General Operation Requirement (GOR) CC-9 dated July 1967 established the overall requirement for MTACCS. MIFASS is one of the fundamental subsystem of MTACCS.

A critical management issue at that time was whether the Army's TACFIRE could be used to satisfy Marine Corps requirements for MIFASS. The Marine Corps decided that TACFIRE could not satisfy the requirements. TACFIRE was designed solely to improve the employment of artillery. It was not able to integrate and coordinate all of the supporting arms. Additionally, it did not meet the size and

weight constraints imposed by amphibious operations. A modification of TACFIRE to satisfy Marine Corps requirements was examined but it was not retained as a viable alternative strategy.

> The difference in the two systems were of such magnitude that the effort to modify the TACFIRE to satisfy Marine Corps requirements would closely approximate the cost and development effort of the MIFASS [Ref. 20: p. 11].

In order to incorporate the latest technology into the system the Marine Corps decided upon the concept of evolutionary design based on "test bed definition". The MTACCS test bed was established in 1979 as an activity of the Marine Corps Development and Education Center (MCDEC) with technical assistance provided by Hughes Aircraft Company under contract to Naval Electronics Command (NAVELEX). The test bed provides an operational laboratory for modeling systems so that improvements, which result from automating selected command and control functions, can be evaluated. [Ref. 13: p.1-1]

The Advance Development Objective (ADO) was published in April 1973. The ADO specified the required IOC date for MIFASS as CY 1980. When the MIFASS Required Operational Capability (ROC) was published in August 1975 the IOC had slipped to CY 1982. [Ref. 21: p. 1]

In September 1978 Hughes Aircraft Company and Norden Systems (a division of United Technologies) were awarded parallel one year contracts to define an approach to the

actual development of MIFASS. A revised ROC was published in July 1979. "In September 1979, the Norden proposal was retained and the company was awarded an approximately $30 million contract to proceed with engineering development." [Ref. 22: p. 433]

The Marine Corps conducted a major review of the MIFASS program in the early part of 1982. The program review was a result of concerns regarding the validity of the MIFASS requirements, impact on mobility, and cost and schedule overruns. The Report of the MIFASS Program Review, completed in April 1982 presents the findings of the work group and recommends four possible courses of action. In June 1982 a decision was reached to continue the development of the MIFASS Engineering Development Model (EDM) as specified in the Acquisition Decision Memorandum (ADM) which resulted from the 22 December 1981 In Progress Review (IPR). [Ref. 23: p. 1]

This thesis assumes that MIFASS (or a derivative of MIFASS) is the long range solution for tactical and technical fire direction at the artillery regiment and battalion. Operational testing and evaluation of the MIFASS EDM is currently in progress. OT II for MIFASS is scheduled for March 1984. [Ref. 24]

MIFASS and TACFIRE will be interoperable. A Memorandum of Understanding has been entered into with the Army to insure an appropriate MIFASS/TACFIRE interface.

As previously discussed, MIFASS and TACFIRE are designed to meet the requirements of battalions and higher headquarters. Both systems can provide firing data for the firing batteries of a battalion. However, they do not allow for autonomous battery operations. During the development of TACFIRE this was recognized as a serious operational deficiency. The Army field artillery research and development community realized that an extension of TACFIRE which would allow for autonomous battery operations was needed. This realization led to the development of the Battery Computer System (BCS).

The MIFASS does not provide a fire direction computer or terminal at the artillery battery level. The MIFASS requirements called for a small hand-held calculator (Fire Direction/Survey Calculator, FD/SC) at the battery level. The Marine Corps realized that the original MIFASS FD/SC did not meet the computational requirements of the firing batteries. Since MIFASS did not provide for a separate enhanced computational capability at the firing battery level, the Marine Corps participated in the development of BCS.

G. BATTERY COMPUTER SYSTEM (BCS)

The Army regards the BCS as the replacement for both the FADAC (at the battery level) and the TACFIRE Battery Display Unit (BDU). The TACFIRE BDU has no computational capability

of its own. It can receive and display fire commands determined by the TACFIRE computer located at the battalion FDC.

The gunnery solution determined by the TACFIRE computer is a battery center to target center solution. This solution does not take into account individual weapon locations or individual aim points. The TACFIRE BDU is a throwback to the old doctrine and automatic data processing (ADP) thinking that was an effect when TACFIRE had its genesis. [Ref. 25: p.23]

Operational testing of TACFIRE, the Artillery 75 Study, the Battle King Study and the series of Helbat tests recognized and established the requirement for an enhanced computational capability at the battery level. It was also recognized that the TACFIRE solution would have to be refined to consider individual weapon locations and individual aim points. Individual weapon corrections allow for greater weapon dispersion which increases survivability and provide better target coverage. To correct these operational deficiencies, BCS development was initiated in the mid 1970's.

The BCS is an automated data processing system which provides the firing battery with high speed two-way digital communications and interface with TACFIRE. BCS is composed of three major units: a Battery Computer Unit (BCU), a Power Distribution Unit (PDU) and Gun Display Units (GDUs). The old wireline intercoms between the battery FDC and the

cannon sections are replaced by the GDUs. The GDU is a remote display unit which interfaces with the BCU and allows for firing data to be displayed at the cannon section. Digital data are transmitted via wire or FM radio. A complete technical description of the BCS is provided in Chapter Five.

Delays in the development of MIFASS and the urgent requirement to increase the responsiveness of artillery fire support caused the Marine Corps in 1976 to consider the acquisition of a "near term" replacement for FADAC. The Marine Corps desired a replacement which could be used at the regiment, battalion and battery levels.

> In recognition of the need to replace FADAC, a proposed Marine Corps FOC for an artillery computer system was published in April 1976. A work directive was promulgated in September 1976, directing MCDEC to explore various sources for providing a follow-on device. [Ref. 26: p. 2]

At the same time, the Army was in the process of initiating the BCS program. The Army approved the ROC for BCS in October 1976 and made a conscious decision to apply existing computer technology to solve the problem. The Army's decision to use the existing computer technology permitted the immediate initiation of full scale engineering development. Norden Systems was awarded the contract for the fabrication of the EDMs.

The Marine Corps decided that the BCS program offered the most cost-effective approach to meeting its "near term" requirements. The Marine Corps planned to use the same

software as the Army for the battery level application, and to develop a modification of this software for use at the battalion and regimental levels. In March 1977 the Army program manager approved an Engineering Change Proposal (ECP) which incorporated the Marine Corps software requirements into the basic BCS contract. [Ref. 26: p. 2]

The BCS was rushed into operational testing and evaluation. THe BCS completed the Army OT II in May 1979. OT II had to be temporarily suspended because of software problems and additional testing scheduled to ensure the fielding of an acceptable product. Over 500 software deficiencies were identified during the development and operational testing. Most of these deficiencies were known prior to the actual commencement of operational testing (OT II). The Army decided to adhere to its self imposed funding constraint and proceeded to OT II without correcting the deficiencies. [Ref. 27: p. 240]

These software problems were in the basic battery level application. The unique Marine Corps software modifications had not been fully developed.

> The initial operational tests conducted on BCS in 1979 had very negative results. They showed that BCS did not meet many of the operational requirements; such as accuracy, interoperability, reliability and maintainability, and did not provide an improved capability over existing equipment. [Ref. 28: p. 2]

In early 1979 MCDEC contracted with Potomac Research Incorporated to conduct a study of alternative replacement

systems for FADAC. This study, A Comparison of Alternative Systems for Meeting Marine Corps Requirements for a Replacement for the M18 Field Artillery Digital Automatic Computer (FADAC) dated 21 June 1979 considered eight alternative systems. It recommended that:

1. The Marine Corps procure a system based on the Magnavox Fire Support Team Digital Message Device (FIST DMD), or equivalent, as the FADAC replacement.

2. The Marine Corps procure the PHHC and appropriate peripherals.

3. The Marine Corps requirements and intentions be made known to the Army prior to the development acceptance IPR scheduled for August 1979.

4. The Marine Corps review and revise as necessary ROC NO SPA-106 for an Artillery Computer System (ACS) to accurately reflect current Marine Coprs requirements.

Recommendations 2,3 and 4 were followed and appropriate action taken.

"The Marine Corps formally withdrew from the BCS program in August 1979 because of dissatisfaction with BCS's ability to centralize battalion fire direction and its high cost." [Ref. 11: p. 62] The Report of the Committee on Appropriations provides four specific reasons for the withdrawal. The decision for withdrawal was based on the high procurement costs for a Marine Corps-unique battalion level program tape, concern over software deficiencies and developments in technology which could provide a smaller, less costly, and more adaptable system.

The problems that BCS experienced during OT II were solvable. In April 1980 Norden Systems was awarded a five

year, multiyear contract for 687 systems. Full scale production and deployment was approved by the Army on 21 May 1982.

> Deployment to USAREUR is scheduled to begin during the second quarter of FY 83 concurrent with TACFIRE fielding. CONUS units will commence receiving their initial issue during the third quarter of FY 83. [Ref. 29: p. 22]

Norden Systems is currently producing the BCS as specified by the multiyear contract. The Marine Corps still has available an option to buy 330 BCSs in FY 83. The option expires on 30 April 1983. The final contract option date for additional BCS procurement is 30 April 1984. However, the Army program manager was not sure if any BCSs would be available to the Marine Corps from the FY 84 final option. [Ref. 4: p. 7-A-B-6]

H. ARTILLERY COMPUTER SYSTEM (ACS)

As a result of the decision to withdraw from the BCS program, the HQMC Sponsor (DC/S PP&O) and the Director, Development Center (C3 Division) began a comprehensive survey of the fire direction computer alternatives that could meet the Marine Corps requirements for an artillery computer system (ACS) [Ref. 30: p. 1]. A Proposed Revision of Required Operational Capability (ROC) NO SPA 1.06, Artillery Computer System dated 12 March 1979 was drafted. It outlined the urgent need for an artillery computer system to replace FADAC and provide Marine artillery with state-of-the-art computer processing of technical fire direction. The

Marine Corps had made a decision to procure state-of-the-art technology instead of existing technology. Program Initiation at Milestone I (Demonstration-Validation) was approved on 3 August 1981.

According to the ADM, the ACS must be a lightweight (under 25 pounds) system which provides ballistic computations and application of nonstandard ballistics data for individual weapons at the artillery battery level. The ACS must use the command, control and communications systems (wire/radio) inherent at the artillery battery level. It must allow for the transmission of firing data via wire or radio from the FDC to the gun display units (GDUs) located at the individual weapons.

The acquisition strategy envisioned building upon other service developments to the maximum extent feasible in order to minimize program risks, costs and development time. Based on this strategy the Magnavox FIST DMD, which was being developed for the Army, was the most promising candidate system. The Potomac Research Study had strongly recommended this system. The development of the ACS is categorized as a less-than-major program for management purposes.

The MIFASS Review (April 1982) effected the development of the ACS. This study determined that the fire control problem was greatest at the battery level and it needed to be resolved as soon as possible. It recommended:

> that, as a matter of priority, HQMC expedite development and/or procurement of an artillery fire direction

computer. To this end, the artillery computer system (ACS) program should be accelerated; its capabilities tested as soon as possible; and procurement of ACS or the Battery Computer System (BCS) begin during FY 83. [Ref. 4: p. ix]

The development of a replacement system for FADAC is to be accomplished separately from the MIFASS development effort. The ACS ROC requires an IOC of 1985. The Marine Corps plans on acquiring 381 ACSs (161 in FY 85 and 220 in FY 86). [Ref. 31: p. 1] The ACS will be procured for all of the artillery regiments (active and reserve). Procurement is to be based on the FY 87 projected force structure. It will support the "3 x 8" structure of the Direct Support artillery battalions. A battery in a direct support battalion will have two computer units, one for each platoon FDC. Additional systems will be procurred for formal school training, prepositioned shipping, spares for a maintenance float and war reserve stocks.

In July 1982 the Army expressed an interest in the Marine Corps ACS as a possible substitute for the BCS in its Light Infantry Divisions. The BCS does not meet the mobility requirements of these divisions. [Ref. 32]

The Marine Corps has used the existing Army FIST DMD contract with Magnavox to initiate development of the ACS. On 30 August 1982, Magnavox submitted an unsolicited proposal for the United States Marine Corps ACS to the Commander, United States Army Communications and Electronics Command (CECOM), Fort Monmouth, New Jersey. This command is managing the acquisition of the Army's FIST DMD. Magnavox

proposed to perform Phase I development of the ACS in accordance with the Marine Corps Statement of Work, dated 27 August 1982. The estimated cost of Phase I development was $566,462. Magnavox's offer to perform was made on a firm fixed price basis.

Magnavox is required to provide four Artillery Computer Units (ACUs) to the Marine Corps for testing in FY 1983. The total cost of the four ACUs was $340,466. Gun Control Units (GCUs) were not included in the Phase I requirement. The GCU is composed of a Section Chief Assembly and two Gun Assemblies. Magnavox is providing the Marine Corps with GCUs so that the ACS can be tested as a complete system. A technical description of the Magnavox ACS is provided in Chapter Five.

OT II for the ACS is scheduled for January 1983. An IPR of ACS is tentitively planned for April 1983. This IPR will review the results of OT II and recommend a decision regarding full scale development and deployment.

This chapter has provided a historical overview of the development of artillery fire direction systems. It addressed the transition from manual fire direction procedures to automated fire direction. The next chapter presents the current status of fire direction in Marine artillery units.

IV. CURRENT STATUS OF FIRE DIRECTION

"If we could first know where we are and whither we are tending, we could better judge what to do and how to do it."

Abraham Lincoln

A. INTRODUCTION

The factual determination of the status quo is a basic requirement of any analysis. A problem statement cannot be properly formulated without a clear understanding of the status quo. This chapter establishes the current status of fire direction in Marine artillery units. The current status was determined based on data provided by artillery Regimental, Battalion and Battery Commanders. Questionnaires and interviews were used to gather relevant data. Inputs from the artillery commanders regarding the characteristics of a new battery level fire direction computer system were also collected. The data were tabulated and analyzed according to the level of command. This chapter presents separately the responses of the different levels of command regarding the current status of fire direction. Additionally, the chapter summarizes the input from all levels of command in order to present a general view of the status quo. Having established the status quo, the chapter defines the problem this thesis addresses.

B. DATA COLLECTION

In July 1982, this author obtained the permission of the four artillery Regimental Commanders to conduct a survey regarding the current status of fire direction. A set of questionnaires was developed to gather the required information. The questionnaires were specifically designed to parallel the three levels of command. The questionnaires and the tabulated responses are provided in Appendices C, D, E.

The questionnaires were mailed to the Regimental Commanders on 30 August 1982. Questionnaires for the 1st Battalion, 12th Marines were mailed directly to the Battalion Commander to save mail time delays. Prior to mailing, the questionnaires were separated into standard battalion packages. The Battalion questionnaires were labeled with a randomly selected letter designator. Battery questionnaires were labeled with the Battalion letter designator and a number (for example K-2, see the last page of the Battalion and Battrey questionnaires).

This labeling allowed data to be aggregated by battalion. In order to preserve anonymity, the Regimental Commanders randomly distributed the battalion packages within their regiment. Battalion commanders randomly distributed the Battery questionnaires within their battalion. Commanders were asked to complete the questionnaire within one week of receipt. A self addressed return envelope was provided with each questionnaire. All questionnaires were

mailed directly to this author's Naval Postgraduate School address. A deadline return date of 20 November was established in order to allow sufficient time to tabulate and analyze the responses.

Questionnaires were sent to all Marine artillery commanders in the current force structure (active and reserve). The current force structure has a total of eighty-one artillery commanders. Table I presents a breakdown of the number of questionnaires returned by the established deadline date.

TABLE I

Questionnaire Response

Echelon of Command	Number of Commanders	Number of Responses	Percentage Returned
Regiment	4	4	100%
Battalion	17	16	94.1%
Battery	60	43	71.7%
Total	81	63	77.8%

At the time this survey was conducted a significant number of Marine artillery units were deployed around the world to support various commitments and participate in multinational exercises. This author received returns from units deployed to Northern Europe and Korea. A 77.8 percent

return rate for a voluntary questionnaire is excellent. This high return rate is indicative of the artillery commanders' concern with fire direction.

Appendices C, D, and E present the tabulated responses for the set of questionnaires. The individual responses have been maintained. Requests for a complete breakdown of the data should be forwarded to the author. An analysis of the responses is presented in the following four sections of this chapter.

C. THE REGIMENTAL COMMANDERS' VIEW

Appendix C provides the tabulated results of the Regimental Commander's questionnaire. The Regimental Commanders support the decentralization of technical fire direction. The primary method of determining firing data varies from regiment to regiment. The 10th Marines is the only regiment which uses FADAC as the primary method of determining firing data at the battery level. Two regiments emphasize the use of FADAC at the battalion level. It is significant to note that over fifty percent of Marine artillery units use the Manual System as the primary means of determining firing.

The level of training of FADAC operators was identified as the problem area associated with FADAC which caused the greatest difficulty for the regiment. The regiments have experienced difficulty in obtaining repair parts for FADAC.

Circuit boards and memory disks were identified as the primary repair parts deficiencies.

All of the Regimental Commanders indicated that they had adequate resources to train the FDC personnel in the operation of the PHHC, TI-59. However, all recommended that Fort Sill, should allocate more instructional hours to the PHHC. The PHHC is definitely being used by the three active regiments.

A majority of the Regimental Commanders stated that the actual computation of firing data produced the largest time delay in mission processing. This answer is not surprising, based on the fact that over fifty percent of the units still use the Manual System as the primary method of determining firing data.

The Regimental Commanders did not assign a very high rating to the importance of fielding a new battery level fire direction system. Specific written comments stated that it should not be fielded until a sufficient number of operators and maintenance personnel have been properly trained on the new system. The Regimental Commanders remember the numerous problems associated with the introduction of FADAC. They want to ensure that the problems associated with the introduction of any new computer system are minimized. They indicated that the new system should be capable of operating from battery and generator power. Additionally, they indicated that the capability to operate

from standard garrison power was a highly desireable characteristic for a new computer system. Comments indicated that this feature would greatly facilitate FDC training and reduce operating costs.

All of the Regimental Commanders identified reliability as the most important characteristic in the selection of a new battery computer system. They want a system that works. Written comments indicated that the new system should be easily maintainable at the user level. A majority responded that the new system should include the automation of the transmission of Fire Commands to the guns. Although all the Regimental Commanders emphasized the decentralization of technical fire direction, a majority indicated that a new battery computer system should have the capability to perform centralized technical fire direction for all firing batteries in a battalion.

D. THE BATTALION COMMANDERS' VIEW

Appendix D provides the tabulated results of the Battalion Commander's questionnaire. The Battalion Commander is responsible for deciding how technical fire direction is exercised in his battalion. The Battalion Commanders unanimously supported the decentralization of technical fire direction. The primary method of determining firing data in the Battalion FDCs is the Manual System. All Marine artillery battalions have a FADAC capability. The reserve

battalions do not use FADAC. All five reserve battalions responded that the Manual System was the primary method for determining firing data in the battalion FDC. This tends to bias the overall results. However, without the reserves no system emerges as the primary method. The active battalions were evenly split between the three different systems. The same situation prevails in the Battery FDCs. The majority of battalions have a current Battalion Gunnery SOP. The primary method of determining firing data in the alternate battalion FDC is the Manual System.

The questionnaires indicated that the operational readiness of FADAC is 59 percent. The Potomac Research Study found that the operational of readiness of FADAC was 57 percent in January 1979. The FADAC operational readiness based on information obtained from HQMC was 79.7 percent as of 15 October 1982. The HQMC was extracted from the Marine Intergated Maintenance Management System (MIMMS) records. The reserves have not been incorporated into the MIMMS. The HQMC data do not reflect the FADAC assigned to the reserve units. [Ref. 33] In this author's opinion, the survey data for FADAC provide a better estimate of FADAC operational readiness and correctly identify the major problem areas. The average FADAC downtime is greater than sixty days. In this author's opinion, this is totally unacceptable. The Battalion Commanders' written comments agree with those of the Regimental Commanders, that the lack of replacement

circuit boards and memory disks is the primary reason for the long maintenance downtimes. FADAC Repairmen (MOS 2885) are all assigned to the Regimental Headquarters Battery. With the execption of the reserves, artillery units are using the integrated FADAC/Manual System. The battalion FDC's proficiency with FADAC was rated as average. Battalion Commanders agreed with the Regimental Commanders that the level of training of FADAC operators is the most serious problem area associated with FADAC.

All battalions are authorized the PHHC, TI-59. The reserve battalions are not using the PHHC. This is evident from their responses to specific questions pertaining to the PHHC. Appendix D indicates those questions which have a bias introduced by the negative responses of the reserve units. The active artillery battalions are using the PHHC. The survey found that the reliability of the PHHC was above average. Its operational readiness was 90 percent. Specific written comments addressed the degradation of the PHHC's performance caused by harsh climatic conditions. The Battalion Commanders stated that the PHHC's performance is definitely degraded by dust and cold weather.

The majority of the Battalion Commanders indicated that they had the resources to adequately train FDC personnel in the operation of the PHHC. They also indicated that Fort Sill should allocate additional instructional hours to the PHHC. The active battalion FDC's proficiency using the PHHC

was rated as average. The proficiency of the reserve battalions was rated as below average to unsatisfactory.

The Battalion Commanders indicated that the largest time delay in mission processing occurred in the actual compuatation of firing data and the voice transmission of Fire Commands to the guns. There was an even split between these two areas. The overall state of training of the battalion FDC was rated as average. No reserve bias was detected in the responses to these questions.

The Battalion Commanders assigned a higher priority to the fielding of a new battery computer system than the Regimental Commanders. They indicated that the new system should be capable of operating from battery and generator power. They rated the importance of the capability to operate from standard garrison power slightly lower than the Regimental Commanders. They definitely support the automation of the transmission of Fire Commands to the guns.

The majority (69 percent) of the Battalion Commanders stated that reliability was the most important characteristic that should be considered in the selection of a new battery computer system. A number of written comments clearly expressed the importance of system reliability. The written comments of the Battalion Commanders also emphasized that the system should be easily maintainable at the Operator/Organizational levels of maintenance. These comments agree with those of the Regimental Commanders.

Although the Battalion Commanders unanimously endorsed the concept of decentralized technical fire direction, eighty-one percent indicated that a new battery computer system should have the capability to perform centralized technical fire direction for all firing batteries in a battalion. Their written comments also expressed a concern that if a new battery computer system is fielded prior to MIFASS, the Battalion FDC would be without an enhanced fire direction capability. This would create a serious gap in capabilities. The battalion FDC would have to continue to rely on FADAC and the PHEC. This view may have influenced their responses in regards to the inclusion of the capability of centralized technical fire direction in a new system.

E. THE BATTERY COMMANDERS' VIEW

Appendix E provides the tabulated results of the Battery Commander's questionnaire. Battery Commanders clearly favored the decentralization of technical fire direction. Three questions (numbers 2, 3, and 4) were used to check the degree of decentralization. All the checks indicated that decentralization of technical fire direction was in fact a reality.

This author was surprised to find that seventy percent of the firing batteries do not have a published Gunnery SOP. The majority of the units that had a Gunnery SOP kept the SOP current.

Fifty-three percent of the Battery Commanders had completed the Field Artillery Officers Advance Course as resident students. Eighty-eight percent of the Battery Commanders had completed a career level school either in residence or by correspondence.

The Manual System is the primary method of determining firing data in the battery FDCs. It should be noted that fourteen of the fifteen reserve batteries responding used the Manual System. The active force structure was evenly split between FADAC, PHHC, and the Manual System. Batteries in the 10th Marines used the FADAC more than batteries in the other regiments. Batteries in the 11th Marines relied on the PHHC as the primary source of firing data. Batteries in the 11th and 14th Marines were not authorized a FADAC. Four reserve batteries indicated that they were authorized a FADAC. Based on the data obtained from the Battery Commanders the operational readiness of battery owned FADACs is 53 percent. The average FADAC downtime is greater than sixty days. This is consistent with the data provided by the Battalion Commanders. A majority of the batteries experienced significant difficulty in obtaining FADAC repair parts. The written comments indicated that circuit boards, memory disks and keyboards are the greatest problem areas. These results agree with the Regimental and Battalion Commanders' assesment. With the exception of the reserves, the majority of artillery batteries authorized a FADAC are

using the integrated FADAC/Manaul System. The battery FDC's proficiency with FADAC was rated as average. The Battery Commanders indicated that the maintenance of FADAC was the most serious problem area for their units. The level of training of FADAC operators was ranked as the second major problem area.

The majority of the reserve batteries are not using the PHHC. This is evident from their responses to the questions pertaining to the PHHC. Appendix E indicates those questions which have a bias introduced by the large number of negative responses from the reserve batteries. The results of the survey show that the active units, primarily the 11th Marines, are using the PHHC. Based on the data obtained the operational readiness of the PHHC is 94 percent. The reliability of the PHHC was rated as above average.

In specific written comments a number of Battery Commanders indicated that the performance of the PHHC was degraded in a desert environment. Additionally, The LED (Light Emitting Diode) display is difficult to read in bright sunlight. The small size of the display degrades the effective supervision of operator inputs.

The Battery Commanders were evenly split over their ability to adequately train FDC personnel in the operation of the PHHC. The majority of the reserve batteries responded that they lacked sufficient resources to conduct proper training on the operation of the PHHC. An overwhelming

majority of Battery Commanders responded that Fort Sill should increase the instructional hours devoted to the PHHC. The active battery FDC's proficiency using the PHHC was rated as above average. Reserve batteries rated their FDC's proficiency with the PHHC as unsatisfactory.

The Battery Commanders responded that the largest time delays in mission processing occurred in the actual computation of firing data. The final results were influenced by the reserve responses. This may be a reflection of their state of training. The majority of the active batteries indicated that the voice transmission of Fire Commands to the guns caused the greatest delays. The overall state of training of the battery FDC was rated as above average to average. The reserve batteries generally rated there overall state of training as average.

The Battery Commanders assigned a higher priority to the fielding of a new computer system than the Regimental or Battalion Commanders. However, the difference in the average ratings (.3) between the Battery Commanders and the Battalion Commanders was not significant. The Battery Commanders responded that a new system should be capable of operating from both battery and generator power. They rated the importance of the capability to operate from standard garrison power higher than the Battalion Commanders but lower than the Regimental Commanders. The majority of the Battery Commanders favor the automation of the transmission of Fire Commands.

Sixty percent of the Battery Commanders stated that reliability was the most important characteristic that should be considered in the selection of a new battery computer system. Specific written comments reinforced the importance of system reliability. The Battery Commanders want a system that works.

Although the overwhelming majority of Battery Commanders currently employ and prefer the decentralization of technical fire direction, they indicated that a new battery computer system should have the capability to perform centralized technical fire direction for all firing batteries in a battalion. This is based on the responses to questions 1, 9 and 42. No reserve bias was detected in these questions.

F. SUMMARY

The questionnaires factually document the current status of Marine artillery. The data from the questionnaires and numerous interviews clearly establishes that Marine artillery units still heavily rely on the Manaual System as the primary means of determining firing data. There is an obvious lack of standardization between the regiments. Each of the three active regiments generally emphasize and employ different methods for determining firing data. Marine artillerymen are required to maintain proficiency in three different fire direction systems. The full impact of the

lack of standardization of a primary method for determining firing data is only ascertained when the number of inter-regimental transfers is considered. During their careers Marines routinely rotate through the different regiments. An Operations Chief who only used the Manual System during his early years generally has a very difficult time mastering the other systems. Marines trained primarily on one particular system are promoted, transferred and required to supervise another system. The Reserves rely solely on the Manual System. The PHHC is not really being used by reserve artillery units.

The data from the questionnaires indicate that:

1. Technical fire direction is decentralized.
2. Batteries do not have current Gunnery SOPs.
3. A majority of artillery Battery Commanders have completed a career level school.
4. The integrated FADAC/Manual System is being used to a limited degree.
5. FADAC maintenance support is inadequate.
6. The PHHC is being used by the active units and its reliability is rated as above average.
7. PHHC Instruction at Fort Sill should be expanded for Marines.
8. A new battery computer system should be capable of being operated from battery and generator power. It should include the automation of the transmission of Fire Commands to the guns.
9. Reliability is the most important characteristic to be considered in the selection of a new battery fire direction computer system. The Commanders want a system that works.

10. The "3 X 8" concept requires two fully equipped Platoon FDCs.

11. Although Commanders employ and prefer the decentralized concept, a significant majority responded that a new battery computer system include the capability to perform centralized technical fire direction for all the firing batteries in a battalion.

The FADAC maintenance support problem is especially critical. The state-of-the-art for FADAC has been passed many years ago. In 1978 the U.S. Army Armament Readiness Command (ARRCOM) reduced the procurement of major long lead time spare and repair parts to prevent excess stocks and unnecessary expenditures. This decision was made in anticipation of the 1980 fielding of the BCS. The slippage of the BCS IOC to FY 1983 impacted on ARRCOM's ability to properly support FADAC. [Ref. 34: p. 12]

> The most recurring problem associated with FADAC supportability is a dwindling source of manufacturing expertise willing and able to produce spare and repair parts. Many of the repair parts have not been manufactured for a number of years, and the current Technical Data Packages (TDP) are out of date. Repeated efforts to obtain up to date TDP's suitable for procurement have met with failure. The Memory Disk Assembly is the most crucial item in the FADAC system. Efforts to procure this item have failed during the past few years. The 90 spare Memory Disk Assemblies (currently available) are all from the Letterkenny Army Depot (LEAD) rebuild program. There are no new FADAC Memory Disk Assemblies remaining in the Army inventory. ALL Memory Disk Assemblies must be repaired by cannibalization of other Memory Disks, resulting in a dwindling supply. Attrition rate for Memory Disks has been about ten units per year. This rate is expected to increase. [Ref. 34: p. 4]

Operational readiness is degraded by the shortage of spare and repair parts. Data from ARRCOM reveal that it

takes from three to four weeks for CONUS units to obtain "normal" replacement parts. "The Memory Disk usually requires six months to a year for replacement." [Ref. 34: p. 7]

ARRCOM plans to support the FADAC system through 1989. The continued support of the FADAC system will be based on cannibalization of existing assets for the major items and additional procurement of miscellaneous minor items (such as resistors, capacitors, transistors, etc.). ARRCOM is considering establishing a maintenance float at Letterkenny Army Depot to support the Army Reserve and Marine Corps FADACs. The float assets will consist of FADACs turned in by active Army units as the BCS is fielded. [Ref. 35]

The Report of The MIFASS Program Review, April 1982 identified the inadequacy of the current fire direction systems. The data from the questionnaires reinforces the findings of the MIFASS Working Group, regarding the current status of fire direction. In this author's opinion, the current Marine artillery fire direction systems are inadequate to meet the demands of today's battlefield. In an age of significant technological advances in computation and automatic data processing systems, the Marine Corps still utilizes a manual system consisting of paper firing charts, plotting pins and GFTs. FADAC is not being used and cannot be relied upon. FADAC was built to meet the field performance requirements needed twenty years ago. It met the

requirements at that time, but new field performance requirements for today's battlefield scenario have made FADAC an outmoded system. The supportability of FADAC has become increasingly difficult. MIFASS is at least five years over the horizon. The most optimistic IOC for MIFASS is FY 1987.

MIFASS will provide the artillery battalion FDC with a state-of-the-art fire support/fire direction computer system. However, MIFASS, as presently configured, does not extend to the battery level. MIFASS will not resolve the fire direction problem at the battery level. The artillery battery needs an automated computational capability to support autonomous battery operations. The fire direction problem is especially critical at the battery level and needs to be expeditously resolved.

Artillery is the MAGTF Commander's primary all-weather fire support asset. The lack of a modern artillery battalion/battery fire direction computer system degrades the Marine Corps overall combat effectiveness. As a result, the Marine Corps faces a critical window of vulnerability, until MIFASS or a derivative of MIFASS is fielded. The current situation requires immediate attention.

The problem definition for this thesis is that the current battery level fire direction systems are inadequate to meet the demands of today's battlefield. This thesis addresses the selection of a Marine artillery battery fire

direction computer system which can significantly enhance the battery's fire direction capabilities. System effectiveness can be improved through the use of automated assistance for the computation of firing data and transmission of Calls-For-Fire and Fire Commands. The technology exists to support the automation of these functions.

This chapter has established the current status of fire direction based on data provided by the questionnaires and interviews, and defined the problem the thesis addresses. Artillery Commanders' inputs regarding the characteristics of a new battery level fire direction computer system were also presented. The next chapter discusses four fire direction computer systems which can enhance battery fire direction capabilities.

V. DESCRIPTION OF ALTERNATIVES

The current status of fire direction in Marine artillery units has been established. The existing fire direction systems are considered inadequate for the battlefield of the 1980's. This chapter provides a description of four battery level fire direction computer systems which can significantly enhance the battery's technical fire direction capabilities. In alphabetical order the four alternative systems are:

1. Artillery Computer System (ACS)
2. Battery Computer System (BCS)
3. Enhanced Fire Direction/Survey Calculator (FD/SC)
4. Fire Control Computer (FCC)

It should be noted that other alternatives exist. American and foreign companies are marketing a number of battery level fire direction computer systems. It was beyond the scope of this thesis to consider all the available fire direction computer systems. This thesis evaluates the four alternatives (listed above) which are currently considered to be prime candidates for replacing FADAC.

The BCS is currently in production and its technical characteristics are firmly established. The other three alternatives are in various stages of development. Some of

their technical characteristics may change as development proceeds. This author has recently visited each of the manufacturers and discussed the technical characteristics with the respective project engineers. The technical data presented in this chapter were provided by the manufacturers of the systems. Additionally, cost data were discussed with representatives of the companies. Cost data presented in this thesis do not represent an offer to produce at the estimated cost. The actual cost can only be established through contract negotiation. Each of the alternatives is discussed separately and then the major characteristics of all the alternatives are summarized in Table XVIII.

A. ALTERNATIVE 1, ARTILLERY COMPUTER SYSTEM (ACS)

The Magnavox ACS is a state-of-the-art automated fire direction system. It combines improvements in the computation of firing data and communications to enhance overall system's effectiveness. The ACS uses the command, control and communications system inherent to the tactical employment of a Marine artillery battery. The ACS consists of an Artillery Computer Unit (ACU) and Gun Control Units (GCUs).

The ACU is the heart of the system. It provides the computational capability and the communications interfaces. The ACU is a lightweight, battery powered, handcarried battery level fire direction computer which provides four separate communications networks for digital or voice

reception/transmission. The ACU digitally passes Fire Commands directly to each howitzer via wire or radio. The ACU also provides for the storage and display of information pertaining to weapon and ammunition status, target and observer locations, meteorological information, and other essential FDC data.

The GCU consists of four pieces of equipment per howitzer; the Gun Control Interface (GCI), the Section Chief Assembly (SCA) and two identical Gun Assemblies (GAs). The GCI provides the interface between the ACU and the SCA and GAs. The SCA is connected to the GCI by a power cable. The two GAs are connected to the GCI by standard field wire (WD-1). The howitzer section chief uses the SCA. The SCA has a display for fire commands and a control keyboard. The GAs provide deflection for the gunner and quadrant elevation for the assistant gunner. The GAs will be mounted on the howitzer.

Physical Characteristics: Table II provides the general physcial characteristics of the ACS. The total weight of the ACS is based on the the equipment required to support an eight gun battery; that is, two ACUs and eight GCUs. The weight of the power cables and the Government Furnished Equipment (GFE) printer that the ACS ROC requires is not included.

TABLE II

ACS Physical Characteristics

Overall Dimensions (in.)	ACU 7.6 (L), 11 (W), 7 (H)
Volume (cu. ft.)	ACU .34
Weight (lbs.)	ACU 19, GCI 10, SCA 4, GA 1
Total Weight (lbs.)	158
Memory Capacity	256K, 16-bit words
Display	ACU, Plasma, 256 Characters approximately 1/4 inch in height
Display Dimensions (in.)	ACU, 7 (W), 3.5 (H)

Power Requirements: The ACU can be powered by internal or external power sources. Internal power is provided by one non-rechargeable Lithium (BA5557/U) battery or one rechargeable Nickel-Cadmium (BB557/U) battery. External power is provided by: external twenty-eight volt (28 volt), direct current (28 VDC) batteries, standard Marine Corps mobile electric power generating sources (MEPGS) and standard garrison power (60 cycle, 120 volts). The external batteries include: non-rechargeable Lithium (BA5590), rechargeable Nickel-Cadmium (BB590) and standard vehicular batteries. The ACU has built-in connections for the external batteries and MEPGS. A small converter is required for the ACU to operate from standard garrison power. The rechargeable

batteries will recharge when the ACU is connected to an external power source.

The operating time provided by internal/external batteries is a function of system usage. The expected operating times of these batteries will be determined as part of developmental and operational testing. Magnavox has found that the Lithium batteries generally last five times longer than the Nickel-Cadmium batteries. The DMD and FIST DMD use the same types of batteries as the ACS.

The GCI is powered by either internal or external power sources. Internal power is provided by one non-rechargeable Lithium (BA5557/U) battery or one rechargeable (BB557/U) battery. External power can be provided by the vehicular electrical system of self propelled weapons. The GCI provides the power supply for the SCA and the two GAs.

Communications Capabilities: The ACU provides communication net switching control for four separate communications networks. Integral connectors for four nets, either wire or radio, are provided. The ACU can receive and transmit digital communications or voice via wire or radio. The ACU has a local terminal node with an internal port into the four net communication switch. Time tags for messages originated at the ACU are provided. The ACS has the capability for time synchronization with net users. The communication net subscriber table allows the ACU to control the communications of subscribers on the nets attached to the system.

The modes of operation for this control include a direct addressing mode, an automated mode and a manual review mode. The ACU provides a net sensing capability to reduce net usage conflicts by multiple users. The ACU can handle 64 subscribers. Encryption compatibilities include the KY-8, 28, 38, and 57 systems. The KG-31 and 84 compatibility is achieved with an appropriate modem card.

Programming and Ballistics: The ACU does not require tape loading of programs. The ACU's firmware contains the programming for all the required weapon systems and the appropriate projectiles, fuzes and propellants. In 1978-79 Magnavox improved the Modified Point Mass Ballistic Model for the U.S. Army's Ballistic Research Laboratory. The ACU's programming uses this Improved Modified Point Mass Ballistic Model. Ballistics are provided for the following calibers: 105mm, 155mm, 8 inch, and 14.5mm trainer. The ACS can compute firing data for all current Marine Corps artillery weapon systems including the M198. ACS can compute individual firing data for sixteen weapons.

Storage Capabilities: Table III contains the current data base storage capabilities for the ACS. The ACU can determine firing data, store weapon and ammunition information, store and apply Registration Corrections and store mask data for sixteen howitzers. The ACU automates ammunition accounting. It can retain three fire plans as part of

its target storage. Provisions have been made to allow the ACU to exchange the Fire Control Directory and Data Base via digital communications with another ACU at a higher headquarters or an adjacent unit utilizing one of its four communications nets or the serial data port.

TABLE III

ACS Storage Capabilities

Targets	60
Known Points	60
FO Locations	10
No Fire Areas	10
Airspace Coordination Areas	1
Meteorological Files	3
Individual Weapon Locations	16
Fire Unit (weapon and ammo) status	16
Concurrent Missions	3 + 1 FPF

Mission Processing: Fire missions can be inputted digitally or manually. The ACS can process three concurrent fire missions plus one Final Protective Fire (FPF). Table IV identifies the types of missions that the ACU is programmed to process.

The ACU will process all three methods of target location: grid, polar and shift from a known point. Using laser generated target or projectile point of impact information (slant range, vertical angle and direction), the ACU computes firing data for stationary and moving targets.

TABLE IV

ACS Mission Processing

Area, Low and High Angle
Registration / Destruction
Illumination / Coordinated Illumination
Air Observer
Time on Target
Laser
Precision Guided Munitions (Copperhead)
Nuclear

Moving target behavior is predicted using linear interpolation techniques. Based on the moving target behavior, the ACU develops target intercept points, time to target intercept, time weapons are to fire, the commands to fire and the FO commands for "shot" and "splash". The ACU provides appropriate alerts for Time on Target missions. A gun-target line adjustment is provided for Air Observer missions. In processing a nuclear fire mission, the ACU computes only the technical firing data for the nuclear projectile.

Auxiliary Functions: The ACU performs a number of auxiliary fire direction functions. One of the major auxiliary functions is the determination of Registration Corrections. It can provide GFT settings for manual back-up. The ACU can determine data for replot. The ACU can determine Muzzle Velocity Variations (MVVs). The M90 Velocimeter readings are manually corrected for projectile weight and propellant

temperature and entered in the ACU. The ACU compares the entered value with a standard value to determine the MVV. Using a set of MVVs, a set of Comparative Velocity Errors (VEs) can be determined. Comparative VEs are needed to transfer GPT settings to non registering batteries. The ACU also computes zone-to-zone transformations. The moving target and "shot" and "splash" functions have already been discussed. The four ACUs being built for OT II are not programmed for standard survey operations. However, Magnavox has indicated that this capability could be added prior to production , if it is required.

Maintenance: The ACU contains a built-in self-test for all firmware. The operator performs this test as part of the preparation for action sequence. It takes approximately seven seconds to run the self-test. Mean Time to Repair (MTTR) for Organizational level repairs (operator repairs) is currently estimated as less than ten minutes. Repair of the ACU is accomplished by the interchange of replaceable modules at the appropriate maintenance level. Mean Time Between Failures (MTBF) is estimated at fifteen hundred hours. The contractor's estimates of MTTR and MTBF will be evaluated as part of OT II.

Ease of Operation: The ACU's programming uses a layering of menus to present information to the operator. The operator calls the system mode menu which causes the

choices of system operation to be displayed. When he selects one of the choices, that selection will bring to the display panel the next menu which contains the additional decisions that the operator must make.

Prompting techniques are used to lead the operator through the sequence of operations he must perform. The display presented to the operator calls attention to the information which the program requires the operator to supply. Default selections are provided in the presentation of some menus, so that the operator is not required to make an entry unless his entry is different from the default (normal standard entry).

If the operator should request the system to do something that violates a previously established "operational rule"; (for example, incorrect projectile / fuze combination, firing into an established no fire area, etc.,) the system will output a warning message to the operator telling him of the conflict and will not honor his request until the conflict is resolved utilizing proper procedures.

This author was able to execute a complete fire mission on the ACS after a ten minute overview briefing on the system. The key to operation of the system is the effective layering of information. The presentation of information was logical and easy to follow. The layering proceeds from a broad overview down to specifics. The presentation of carefully sorted data enhances the operation of the system. The

display is clear and very easy to read. The characters are evenly distributed and the alignment is excellent. Common artillery abbreviations have been used wherever possible. The operator is not required to memorize a list of new mnemonics. System prompts are used effectively to guide the operator. The system can be classified as "user friendly".

Magnavox's attention to human engineering is clearly evident. The size of the display characters (approximately 1/4 inch), effective layering of information and the use of system prompts contribute to the ease of operation. The display panel can easily be read by the FDO. Visual and audio alerts are provided for the operator. The system is definitely easier to operate than FADAC.

The ACU has a directory feature which allows the operator to search information in his data base in response to questions concerning targets, mission status, forward observers, weapons, etc. This feature permits questioning the system for information without the requirement of the operator asking for each piece of information that he wants separately. Essentially the directory feature allows the operator to know what is planned, and what is currently happening, in his area of interest. The directory feature uses layering and sorted data to provide the information.

Commonality: Approximately ninety percent of the ACU's hardware is common to other systems [Ref. 36]. The ACS will be produced on the same production line that was established

for the Army's DMD (AN PSG-2) and FIST DMD. Magnavox's Communication Message Device (CMD) becomes an ACU with the loading of programs to accomplish the ACS system tasks. The programs are contained on two Electrically Programmable Read Only Memory (EPROM) cards and one Arithmetic Processing Memory (APM) card. The ACU will use the actual FIST DMD box.

Although the ACS would be a unique Marine Corps system, the majority of its components are used in a number of Army systems. The Marine Corps maintenance effort should benefit from the high degree of commonality of basic components.

Magnavox has produced 2000 DMDs and currently a total of 7000 are to be fielded. Approximately 1200 FIST DMDs are to be fielded.

> Force Development Test and Experimentaion Testing of the FIST DMD was conducted at Fort Sill by the U.S. Army Field Artillery Board during July and August of this year. Preliminary findings based on emerging test results indicate the FIST DMD performance to be favorable. [Ref. 37: p. 21]

The hardware commonality should significantly reduce logistics costs. Additionally, the Marine Corps should be able to take advantage of Magnavox's production learning curve. The initial production line problems associated with any new system start-up have already been resolved. The Marine Corps 381 ACUs represent only a small fraction of the items to be produced on this production line. No major modifications of the production line are required for the ACS.

Interoperability: The ACS ROC requires that, the ACS will incorporate automated assisted (operator action required prior to message being entered into memory) interface with the Meteorological Data System (MDS) and the Digital Communications Terminal (DCT). ACS will also be compatible with and incorporate an automated interface with MIFASS when MIFASS is fielded. [Ref. 38: p. 6]

MDS is an Army program to develop an improved field artillery meteorological system. It will have the capability of providing an automated assisted digital meteorological data input directly to an artillery fire direction computer. It is being developed by Bendix and its projected IOC for the Marine Corps is FY 1984. The DCT is a Marine Corps developed, small, hand-held manually operated device for sending and receiving digital, fixed format and free-text messages over wire and voice radio nets. The DCT is being developed by Litton. The projected DCT IOC is FY 1985. MIFASS was discussed in Chapter Three. The MIFASS EDMs are being built by Norden Systems. The projected MIFASS IOC is FY 1987. All of these systems (ACS, MDS, DCT, MIFASS) are still in various stages of development and are being built by different contractors. Interoperability will be a problem, but it is solvable.

The ACS must be able to use input from the M90 Velocimeter and the AN/TPQ-36 Radar. The M90 was fielded in FY 1981. It provides accurate and timely determination of

weapon muzzle velocities. These muzzle velocities can be manually entered into the ACU. The M90 does not have or require an automated interface.

The AN/TPQ-36 hostile weapon locating radar has the capability for a digital data link with a fire direction computer. The AN/TPQ-36 is currently being fielded by the Marine Corps. The ACS automatically interoperates with the AN/TPQ-36.

Magnavox is working towards developing the interfaces for MDS and the DCT. These interfaces would be included in the production version of the ACS. Since the final version of MIFASS has not been decided, Magnavox has recommended that the MIFASS interface be a preplanned product improvement for the ACS. Sufficient memory has been allocated for the required interfaces. The FIST DMD interoperates with BCS/TACFIRE. Since ACS is in reality a derivative of the FIST DMD, the communications interface between ACS and BCS/TACFIRE is not a major problem.

Procurement Cost: Procurement cost is based on a FY 1984 procurement of the ACS. Table V presents the current estimate of the ACS procurement cost for an eight gun battery. All costs in Table V are in FY 1984 dollars.

The ACU's high degree of commonality has allowed Magnavox to establish a good estimate of the ACU's cost. There is some uncertainty concerning the cost of the GDU (composed of the GCI, SCA and 2 GAs). Magnavox provided a

TABLE V

ACS Estimated Procurement Cost

Item	Cost Per Item	Number Required	Total Cost
ACU	$35,000	2	$70,000
GDU	$4,000	8	$32,000
			$102,000

range of from $3,000 to $5,000 per GDU [Ref. 36]. Table IV uses the average of the low and high estimates. If the low and high estimates are used, the total cost per battery may be as low as $94,000 and as high as $110,000.

B. ALTERNATIVE 2, BATTERY COMPUTER SYSTEM (BCS)

The BCS is a lightweight, self contained, twenty-eight-volt (28-volt) direct current powered central computing subsystem which performs the processing, display and control functions for artillery battery fire direction [Ref. 4: p. 1, Encl 7]. BCS is an automated data processing system which provides the firing battery with high speed two way digital communications and interface with TACFIRE, DMD, Ground Stations of Remotely Piloted Vehicles (RPVs), AN/TPQ-36 Radar and MDS. The BCS is the battery level extension of TACFIRE. It refines the TACFIRE solution and provides individual piece corrections. Its employment and

capability are optimized for artillery battery use in performing survey tasks and technical fire direction. It enhances responsiveness and minimizes FDC transmission errors by digitally sending Fire Commands from the FDC to each howitzer.

The BCS replaces the M 18 FADAC and the TACFIRE BDU in all Army field artillery batteries to include some Reserve and National Guard units. The BCS is capable of autonomous battery operations. The BCS normally will be mounted in the M577 Command Post Carrier (a tracked vehicle) or the M561 Gamma Goat (a wheeled vehicle). The BCS can also be table mounted for ground operations. It is being produced by Norden Systems and initial fielding commences during the second quarter FY 1983. The BCS cosists of three major units: a Battery Computer Unit (BCU), a Power Distribution Unit (PDU) and Gun Display Units (GDUs).

The BCU contains all the controls, displays, and indicators required for the initiation and implementation of fire missions and associated activities. The BCU performs all calculations and interfaces with existing radios, communications security (COMSEC) devices and the GDUs. The BCU has a twenty-four line plasma display panel, an alphanumeric, special function keyboard, three communications ports (two external and one internal), and a program load unit. The communications networks allow for the reception / transmission of digital communications or voice via wire or radio.

The PDU receives primary system power from either vehicular battery power or from a DC generator. The PDU distributes incoming power to the BCU, COMSEC equipment, and radios. The PDU is equipped with a trickle charger to maintain the BCU's internal emergency batteries in a constant state of charge.

The GDU receives piece data and Fire Commands from the BCU and displays them at the howitzer section. It also transmits the weapon status to the FDC as a fire mission progresses. The GDU consists of a Case Assemly, Section Chief Assembly (SCA) and two identical Gun Assemblies (GAs). The Case Assembly provides the interface between the BCU and the SCA and GAs. It also serves as the power distribution source for the SCA and GAs. Each section chief receives his howitzer's Fire Commands on the SCA while the deflection and quadrant elevation are simultaneously displayed on the gunner and assistant gunner GA's respectively. The GA's will be mounted on the howitzer.

Physical Characteristics: Table VI provides the general physical characteristics of the BCS. The total weight of the BCS is based on the equipment required to support an eight gun battery; that is, two BCUs and eight GDUs. The weight of the required power cables and the GFE printer is not included.

Power Requirements: The BCU is powered by either vehicular batteries (28 VDC) or a DC generator (1.5KW). To

TABLE VI

BCS Physical Characteristics

Overall Dimensions (in.)	BCU 24 (L), 17 (W), 18 (H) PDU 20 (L), 19 (W), 5.5 (H) Case 20.3 (L), 12.8 (W), 14 (H) SCA 9.4 (L), 4.4 (W), 2.2 (H) GA 6.2 (L), 4.8 (W), 1.8 (H)
Volume (cu. ft.)	BCU 4 PDU 1
Weight (lbs.)	BCU 90 PDU 30 Table 73 Case 25.2 SCA 2.3 GA 1.5
Total weight (lbs.)	634
Memory	128K, 24-bit words
Display	BCU, plasma, 24 lines with 72 characters per line, 1728 total characters, approximately 1/8 inch in height
Display Dimensions (in.)	BCU, 10 (W), 5 (H)

protect the memory contents in the event of primary external power loss, the BCU is equipped with a power backup system consisting of two Nickel-Cadmium internal emergency batteries (BB590/U). These batteries provide power to the BCU memory for up to two hours, thus allowing for the repair and return of primary power without total memory loss. The PDU trickle charger maintains these batteries in a constant state of charge.

The GDU Case Assembly serves as the power source for the SCA and two GAs. The power options include internal battery power (BA5590 Lithium), vehicular battery power and DC generator power. [Ref. 39: p. 1-19]

Communications Capabilities: The BCS uses standard communications equipment (wire and radio) to communicate by digital and voice transmission. The BCU has three communications channels. Two external channels provide high speed digital communications or voice with the elements of the field artillery system. Channel 1 is normally the Battery Fire Direction net. It serves as the primary link with TACFIRE. Channel 2 would handle any other nets the battery needs to utilize. The FDC uses the channel 2 radio to switch to the appropriate frequency prior to communicating with any channel 2 subscriber. The internal channel is used to support the GDUs. The internal channel can communicate over wire or radio. The FDO can communicate on any channel by turning his handset channel selector to the desired channel and monitoring/speaking on that channel through the FDO handset. The BCU allows for the composition and editing of messages.

The PDU permits on line teletype with the GCX-74. Encryption compatibilities include only the newer COMSEC devices, KY-57 and KG-31 and 84. There are currently no plans to require secure communications for the AN/PRC-68 on the GDU net due to its limited range.

Programming and Ballistics: The BCU requires the loading of a magnetic tape prior to operation. The BCS Cannon Application Program consists of an operating system, diagnostic module and a weapon dependent program with data base. The program load unit located beneath the BCU loads the software program in less than one minute. The software program contains sixteen different caliber and model combinations for the 105mm, 155mm, 8 inch and 14.5mm trainer. Every artillery cannon unit has the same tape. The operator initializes the ECU for the specific weapon system desired. The software program contains all the authorized projectiles, fuzes and propellants for each weapon system.

Ballistics data are based on the older Modified Point Mass Model. The BCS can compute firing data for all current Marine Corps artillery weapon systems including the M198. BCS can compute individual firing data for twelve weapons. BCS will determine firing data using individual piece locations, individual piece muzzle velocity variations, individual piece aimpoints and by flying individual ballistic trajectories.

Storage Capabilities: Table VII contains the data base storage capabilities for the BCS. The BCU can determine firing data, and store weapon and ammunition information for twelve howitzers. However, the BCU can only store and apply eight different mask inputs. Eight sets of Registration Corrections can be stored. The appropriate set of

Registration Corrections is applied to all howitzers firing a mission. The BCU can store three fire plans as part of its data base. Fire planning data can be automatically inputted from another BCU, TACFIRE or DMD.

TABLE VII

BCS Storage Capabilities

Targets	60
Known Points	60
FO Locations	10
No Fire Areas	10
Airspace Coordination Areas	0
Meteorological Files	3
Individual Weapon Locations	12
Fire Unit (weapon/ammo) status	12
Concurrent Missions	3, + 1 FPF, 1 CP Msn

Mission Processing: Fire missions can be inputted digitally or manually. The BCS can process three concurrent fire missions plus one Final Protective Fire (FPF) and one Copperhead Priority mission (CP Msn). Table VIII identifies the types of missions that the BCU is programmed to process.

The BCU will process all three methods of target location: grid, polar and shift from a known point. The BCU can use laser generated target information to determine firing data for a stationary or moving target. When used with the Ground Laser Locator Designator (GLLD), the BCU has the

TABLE VIII

BCS Mission Processing

Area, Low and High Angle
Registration / Destruction
Illumination / Coordinated Illumination
Air Observer
Time on Target
Laser
Precision Guided Munitions (Copperhead)
Targets in a Fire Plan
Nuclear

capability to assist in observer self location by trilateration or resection or to attack irregularly shaped targets through a draw routine.

The BCU provides appropriate alerts for Time on Target missions and the execution of fire plans. A visual countdown clock keeps the BCU operator abreast of fire plan timing. When the BCS operates with TACFIRE, tactical fire direction is provided by TACFIRE. TACFIRE selects the unit(s) to fire, the shell/fuze combination, and determines the number of volleys required to defeat the target while conforming with the commander's guidance. In autonomous employment, tactical fire direction decisions are made by the FDO and manually inserted by the BCU operator. Default selections can be established by the operator based on the FDC's Fire Order/Fire Command standards.

Auxiliary Functions: The BCU performs a number of auxiliary fire direction functions. One of its primary auxiliary functions is the determination of Registration Corrections. The BCU provides GFT settings for manual back-up. The BCU can determine data for replot. The BCU uses input from the M90 Velocimeter to determine MVVs. The M90 muzzle velocity readings must first be manually corrected for projectile weight and propellant temperature. This corrected muzzle velocity is entered into the BCU. The BCS compares the entered muzzle velocity with the standard muzzzle velocity for the specified projectile/propellant lot/charge to determine the MVV. The BCS software was designed to allow the transfer of MVVs to other charges in the same projectile/propellant group, but no restriction for different lots was imposed. It thus remains the FDO's responsibility to manage the lots of ammunition. Using a set of related MVVs, a set of Comparative VEs can be manually determined. Comparative VEs are needed to transfer GFT settings. The BCS can perform zone-to-zone transformations. It also provides "shot" and "splash" to the observers.

Maintenance: The BCS was designed to concentrate maintenance activity at the Operator level so as to avoid costly evaluation downtime [Ref. 40]. The operator can correct ninety percent of all system faults in field replaceable items within thirty minutes.

The BCS contains a self diagnostic program which assists the operator in isolating problems. The operator's manual (TM 11-7440-283-12-1) provides a list of troubleshooting procedures. As part of these procedures the operator may be directed to a specific diagnostic routine. The BCS has six diagnostic test routines:

1. Display,
2. Keyboard,
3. Printer,
4. Communications Channels,
5. GDU Channel, and
6. Front Panel.

The BSU displays all necessary instructions for the operator and provides the results of each test. When a test is failed, the BCU tells the operator which BCU module (there are eleven total) to replace. Organizational maintenance is limited to the replacement of these modules.

The BCS's MTTR is thirty minutes and MTBF is twelve hundred hours. These estimates are based on the data available from developmental and operational testing.

Ease of Operation: The BCS programming automates as much of the fire direction process as possible while still retaining the allowance for FDO intervention. The BCU has an alphanumeric, special function keyboard. The operator uses the alphanumeric keys with a list of operator options presented on the front panel display. The special function

keys allow special tasks to be initiated by the operator; that is, gun command keys, display operation keys and execute key. The basic keyboard is similiar to the standard computer terminal keyboard. The keyboard folds up to cover the display area/front panel during movement.

The display area on the BCU front panel is a plasma type display on which 24 lines of 72 characters each can be displayed. The display is divided into three functional areas:

1. Upper display. Contains mission status of current fire missions. It has 5 lines of display.

2. Middle area. Contains gun status, date time, and data file status. It has 4 lines of display.

3. Lower display. Used for displaying incoming messages, error warning messages, firing data, and messages stored in queues, composing and editing messages, and displaying editing established files. It has 14 lines of display.

An operator-prompt capability presents at the bottom of the display the range of legal values for the field in which the cursor is currently located. Operation of the BCS is based on the use of standard message formats and the extensive use of mnemonics. The rough draft of TC 6-1-2, Battery Computer System lists 36 standard message formats. The Glossary to this TC provides a dictionary of 276 mnemonics in addition to those used for projectile and fuze identification. It takes time for an operator to become familiar with the basic mnemonics. Initially operators rely heavily on the published list of mnemonics.

In this author's opinion, the BCS is more complicated than FADAC. It appears to be more difficult to learn how to operate the BCS than FADAC. The BCS requires a great deal of memorization. Data input requires a large amount of typing. Using FADAC as a baseline, there is a significant increase in the amount of typing. The BCS operator is required to type in text, mnemonics and numbers.

USAFAS is currently planning to allocate 120 hours of instruction on BCS to the Officer Basic Course students. BCS requires a degree of field artillery system understanding beyond the simple generation of technical firing data. USAFAS has recommended that due to the increasing complexity and responsibility of the duties of the FDO, the senior lieutenant in the firing battery should be the FDO. [Ref. 40]

Officers attending the Field Artillery Officers Advance Course and Non-Commissioned Officers (NCOs) attending the Field Artillery Cannon Advanced Course will receive approximately 40 hours of instruction on the BCS. This instruction will include familiarization with the BCS's characteristics and capabilities, constructing data bases and processing of TACFIRE or autonomous fire missions. The organization of a BCS operator's course is currently under consideration. It has been estimated that approximately 80 hours of instruction would be required for a basic operator's course. [Ref. 41] Regardless of the amount of formal training

provided to operators, proficiency is only attained and maintained through unit training. USAFAS is studying the possibility of obtaining training simulators which could be programmed to display specific messages in support of structured training exercises. A BCS insertable, fixed format tape, which would simulate the TACFIRE and DMD interface is being pursued to support initial BCS fielding and serve as a temporary expedient prior to fielding of the programmable training simulators.

Commonality: If this alternative is selected the Marine Corps and the Army would have the same battery level fire direction computer. The Marine Corps would be able to take full advantage of common logistics and training support. Training and maintenance publications have already been developed. Software maintenance would be performed by the Army (USAFAS, Gunnery Department) in the same manner that FADAC tapes were updated.

The BCS serves as the extension of the Army's TACFIRE. BCS capabilities are optimized when it is linked to TACFIRE. The Army's training will be structured to support the BCS/TACFIRE interface. The Marine Corps training will have to be modified to emphasize BCS autonomous operations.

Interoperability: The BCS interoperates with another BCS, TACFIRE and the DMD or FIST DMD. Norden Systems is the developer and producer of BCS and is currently under

contract for the MIFASS EDMs. MIFASS interface problems would be minimized, since the same company has worked on both systems. Only one of the systems (MIFASS) is still under development.

Additionally, the BCS will interface with the M90 Velocimeter, AN/TPQ-36 and the MDS. The Marine Corps would not have to test these interfaces since all three programs were designed and developed to support the Army's BCS/TACFIRE concept of employment.

An interface for the BCS and DCT will have to be developed. The Marine Corps will have to test this interface. Norden Systems is not currently working on a BCS/DCT interface. Since the BCS is in production, a rational approach would be to modify the DCT to meet the BCS requirements for interface.

Procurement Cost: Procurement costs are based on a FY 1984 procurement of the BCS. Table IX presents the current estimate of the BCS procurement cost for an eight gun battery. The Army has decided to provide two complete BCUs for its eight gun batteries. All costs in Table IX are in FY 1984 dollars.

These costs are based on a Marine Corps buy under the existing firm fixed price contract [Ref. 4: p. 7-A-B-6]. If the Marine Corps is not able to procure the BCS under the existing contract option date (30 April 1983 and 30 April 1984), a new contract will have to be re-negotiated with

TABLE IX

BCS Procurement Cost

Item	Cost Per Item	Number Required	Total Cost
BCU/PDU	$120,122	2	$240,244
GDU	$ 12,452	8	$ 99,616
			$339,860

Norden Systems. A re-negotiation of the contact will most probably result in higher costs than those identified in Table IX.

C. ALTERNATIVE 3, ENHANCED FIRE DIRECTION/SURVEY CALCULATOR (FD/SC)

The Enhanced FD/SC has evolved from the stand-alone FD/SC required in the original MIFASS program specifications. The MIFASS requirements called for a small, hand-held calculator at the artillery battery level. This calculator was supposed to support autonomous battery operations. The original requirements closely parallel the capabilities of the PHHC, TI-59.

In the late 1970's the Marine Corps development community realized that the FD/SC would not meet the operational requirements of an artillery battery on the battlefield of the 1980's and beyond. This was one of the reasons that

prompted the Marine Corps to participate in the development of BCS. Chapter Three discussed the reasons for the Marine Corps withdrawal from the BCS program.

After the Marine Corps withdrew from the BCS program, Norden Systems submitted a "no cost to the government" engineering change proposal (ECP) to enhance the FD/SC. As part of the MIFASS contract, Norden was required to provide eleven FD/SC EDMs to the Marine Corps. However, the ECP reduced the number of FD/SC EDMs to two. Norden is currently under contract to deliver two Enhanced FD/SC EDMs to the Marine Corps in March 1983. [Ref. 24]

Norden is in the process of submitting a proposal to further enhance the FD/SC, so that it meets or exceeds the capabilities specified in the Marine Corps ACS ROC. Norden's proposal is to produce and field the Enhanced FD/SC as currently specified in the FD/SC Program Performance Specification 2157-S-0110 and ECP 0001. Additionally, Norden plans to include a digital GDU communications channel that is not addressed in these specifications. [Ref. 42]

If a production decision is made in July 1983. Norden projects that initial deliveries of the Enhanced FD/SC could be made in the third quarter FY 1984. [Ref. 43: p. 62]

Further enhancement of the FD/SC would be based on the concept of preplanned product improvement (P3I). The P3I would not require any hardware changes. It is based solely on additions to existing software. Software additions are

required to provide full digital communications and graphics capabilities. Norden envisions the P3I being accomplished in two separate phases. The first phase would provide the software additions necessary to support the full digital communications capability. The second phase would provide the software additions necessary for a graphics situation display complete with fire support coordination measures. [Ref. 44]

Alternative 3 is the Enhanced FD/SC in its final form; that is, complete with communications and graphics capabilities. The technical description will identify current Enhanced FD/SC capabilities and the additional capabilities that can be provided by Norden's proposed P3I.

The Enhanced FD/SC is a state-of-the-art automated fire direction system. The Enhanced FD/SC in its final form combines improvements in the computation of firing data, communications and graphics to enhance overall system's effectiveness. The Enhanced FD/SC uses the command, control and communications systems inherent to the tactical employment of a Marine artillery battery. The complete battery level fire direction system consists of the Enhanced FD/SC and the GDUs.

The Enhanced FD/SC is a self-contained, command, control and communications terminal. It provides for integrated or stand-alone tactical and technical program control, information storage, processing, computation, fixed and

programmable key entry, and display of fire direction or survey data. The Enhanced FD/SC is a lightweight, battery powered, handcarried fire direction computer. The Enhanced FD/SC functionally consists of a central processor, communications processor, modems, memory, fixed keys, display, interactive device, asynchronous serial interfaces and power source. The Enhanced FD/SC programs and data are retained and automatically restored during power cycling, eliminating the need for a program loading device. The Enhanced FD/SC hardware will have four dual purpose communications channels and one GDU channel. The dual purpose channels will provide for digital or voice reception/transmission via wire or radio. The GDU channel will provide for the digital transmission of firing data from the FD/SC to the GDUs via wire or radio. The digital GDU channel will be included in the Enhanced FD/SC EDMs. The software to support the four dual purpose communications channels will be part of the P3I.

The GDU which was developed by Norden for the BCS will be used in this system. The GDU consists of a Case Assembly, SCA and two GAs. The Case Assembly provides the interface between the FD/SC and the SCA and two GAs. It also serves as the power source for the SCA and GAs. Each section chief receives his howitzer's Fire Commands on the SCA while the deflection and quadrant elevation are simultaneously displayed on the gunner and assistant gunner GA's respectively. The GAs will be mounted on the howitzer.

Physical Characteristics: Table X provides the general physical characteristics of the Enhanced FD/SC. The total weight of the system is based on the equipment required to support an eight gun battery; that is two FD/SCs and eight GDUs. The weight of the required power cables and GFE printer is not included.

TABLE X

Enhanced FD/SC Physical Characteristics

Overall Dimensions (in.)	FD/SC	18.8(L), 12.5(W), 6.6(H)
	Case	20.3(L), 12.8(W), 14 (H)
	SCA	9.4(L), 4.4(W), 2.2(H)
	GA	6.2(L), 4.8(W), 1.8(H)
Volume (cu. ft.)	FD/SC	.89
Weight (lbs.)	FD/SC	35
	Case	25.2
	SCA	2.3
	GA	1.5
Total Weight (lbs.)		302
Memory		720K, 24-bit words
Display		FD/SC, plasma overlayed with an interactive device, left half, 25 lines with 36 characters per line, 900 total characters, approximately 1/8 inch in height
Display Dimensions (in.)	FD/SC	9.72 (W), 4.75 (H)

The Enhanced FD/SC's memory can be expanded to 816K Bytes with the addition of an internal plug-in memory module. The Enhanced FD/SC's memory could be further expanded to 2000K Bytes based on projected technological advances in the size reduction of memory modules or the incorporation of a peripheral add-on mass memory. Norden believes that a 2000K Byte memory based on smaller sized memory modules could be installed inside the current Enhanced FD/SC hardware. [Ref. 42]

The Enhanced FD/SC will use only the left half of the total display area. This allows for the presentation of twenty-five lines with thirty-six characters per line (total nine hundred characters). The left half of the display will be used for displaying text and programmable switches to implement the fire direction and survey functions. The left half of the display is 4.86 inches wide and 4.75 inches high. The right half of the display is reserved for the graphics capability. When the graphics capability is added the display will allow for the presentation of eighteen hundred characters.

The plasma display is overlayed with an interactive device. This device provides the capability to hook or designate a specific location on the display surface for programmable item selection. A finger or stylus can be used to activate the interactive device. Actual touching of the display surface is not required. Finger travel within .45

inch of the display surface will activate the interactive device. The Enhanced FD/SC is the only alternative which has an interactive display.

Power Requirements: The Enhanced FD/SC can be powered by internal or external power sources. Internal power is provided by three non-rechargeable Lithium stick (BA5600/U) batteries or ten rechargeable sealed lead acid D-cell (BA30) batteries. External power is provided by: the external MIFASS Battery Box (2157-S-0019), 28 VDC vehicular batteries, and standard MEPGS. The addition of a small converter allows the use of standard garrison power (60 cycle, 120 volts). The rechargeable internal batteries will recharge when the Enhanced FD/SC is connected to an external power source.

The Enhanced FD/SC has a power conservation feature. When power is on and the Enhanced FD/SC is not actively performing one of its specified functions, it will save its current status and go into a power conserving idle mode. In this mode, the Enhanced FD/SC will blank the display, retain all information in memory, keep the power indicator on, and be capable of returning to the active mode after receipt of an incoming message or a fixed key depression without the loss or modification of any data. After returning to the active mode the Enhanced FD/SC will continue normal operation from its last period of active operation.

Based on the operational scenario presented in the MIFASS specifications, Norden has estimated the expected operating life of the internal batteries. The expected operating life is currently estimated at twenty-two hours for the Lithium batteries and four-and-a-half hours for the rechargeable sealed lead acid D-cells. The operating time provided by these batteries is a function of system usage. The expected operating time of these batteries would be evaluated during developmental and operational testing.

The GDU Case Assembly serves as the power source for the SCA and GAs. The power options include internal battery power and DC generator power.

Communications: The Enhanced FD/SC currently does not have a communications capability. The Enhanced FD/SC hardware is designed to provide four dual purpose communications channels and one GDU channel. Norden plans to include the software required to support a digital GDU communications channel in the Enhanced FD/SC EDMs scheduled for delivery to the Marine Corps in March 1983. The existing Enhanced FD/SC specifications do not require this capability. The software required to operate the four dual purpose communications channels is the first phase of Norden's P3I proposal.

The final version of the Enhanced FD/SC provides for digital or voice communications via wire or radio over the four dual purpose channels. The GDU net will provide for the digital transmission of firing data from the Enhanced

FD/SC to the GDUs via wire or radio. The GDU net does not provide for voice communications.

The dual purpose channels will support the DCT and AN/TPQ 36 interface. The Enhanced FD/SC will provide a net sensing capability to reduce net usage conflicts by multiple users. The Enhanced FD/SC will be able to handle sixty-four subscribers. Encryption compatibilities include the KY 57, KG 31 and 84 COMSEC systems.

Programming and Ballistics: The Enhanced FD/SC does not require tape loading of programs. The Enhanced FD/SC programs and data are retained and automatically restored during power cycling, eliminating the need for a program loading device. The initialization function provides the displays and menu selections necessary to initialize the permanent data files.

The Enhanced FD/SC programming uses the Modified Point Mass Ballistic Model. Norden has proposed that the Improved Modified Point Mass Ballistic Model be incorporated into the Enhanced FD/SC's software as part of the P3I. Ballistics are provided for the following calibers: 105mm, 155mm, 8 inch, and 81mm. Nine different weapon system models are included in the software. The Enhanced FD/SC can compute firing data for all current Marine Corps artillery weapon systems including the M198. All weapons and ammunition data used in ballistic computations is stored in plug-in Read Only Memory (ROM). The FD/SC can compute individual firing data for eight weapons.

Storage Capabilities: Table XI contains the current and proposed data base storage capabilities for the Enhanced FD/SC. The Enhanced FD/SC can determine firing data, store basic weapon and ammunition information, and apply Registration Corrections for eight weapons.

TABLE XI

Enhanced FD/SC Storage Capabilities

File	Current	Proposed
Targets	50	100
Known Points	50	100
FO Locations	30	30
Fire Support Coordination Measures	0	10
Meteorological	2	3
Individual Weapon Locations	8	8
Individual Weapon MVs	8	8
Concurrent Missions	2	3, + 1 FPF

The software additions would provide ammunition accounting, increased target and known point files, fire support coordination measures, increased concurrent mission capability and storage for fire plans.

Mission Processing: Currently fire missions can only be manually inputted. When the firing data is determined it can be transmitted digitally from the FDC to the guns via wire or radio. The first phase of the P3I proposal provides the full digital communications capabilities for the system. In

its present configuration the Enhanced FD/SC can only compute two concurrent fire missions. Table XII identifies the types of missions that the Enhanced FD/SC is programmed to process.

TABLE XII

Enhanced FD/SC Mission Processing

Area, Low and High Angle
Registration / Destruction
Illumination / Coordinated Illumination
Air Observer
Nuclear

The Enhanced FD/SC will process all three methods of target location: grid, polar and shift from a known point. A gun-target line adjustment is provided for Air Observer missions. In processing a nuclear fire mission, the Enhanced FD/SC computes only the technical firing data.

Software mission processing additions would include: Fire Plan execution, Laser (stationary or moving target) and Precision Guided Munitions (Copperhead).

Auxiliary Functions: The Enhanced FD/SC performs a number of auxiliary fire directon functions. One of the major auxiliary functions is the determination of Registration Corrections. It can currently store and apply four different sets of Registration Corrections. Software

additions will increase this to six sets. The Enhanced FD/SC provides GFT settings for manual backup. It can determine data for replot. The Enhanced FD/SC stores and applies weapon muzzle velocities. M90 Velocimeter readings must be manually corrected for projectile weight and propellant temperature to determine the weapon muzzle velocity. MVV and Comparative VEs must be manually determined.

The Enhanced FD/SC is programmed to perform all the standard survey operations. It also computes zone-to-zone transformations. Its survey capabilities are excellent.

Maintenance: The Enhanced FD/SC contains a built-in self-test which monitors performance and can be used at the Organizational and Intermediate levels of maintenance. The built-in self-test is initiated by the operator via a menu selection. The operator performs the built-in self-test as part of the preparation for action sequence. The test verifies the proper operation of all primary memories, keyboard, display, alarm, battery charging and power functions. The proper operation of all central processor instructions, memory addressing, buffering and input/output functions will also be verified. Additionally, the capability and proper operation of communications processors, spare memory and asynchronous serial interface is verified. The built-in self-test is able to detect ninety-five percent of the faults in the Enhanced FD/SC. An alarm is provided to the operator to indicate failure of the test. The Fail Indicator

illuminates when the Enhanced FD/SC has failed either a performance monitoring or the built-in self-test and is no longer operational.

The Enhanced FD/SC is constructed to provide ease of maintenance, accessibility and replacement of all modules and printed circuit boards by maintenance personnel. Organizational level maintenance is performed by the operator using the built-in self-test and/or go/no-go diagnostic firmware to identify a failed unit. No support or test equipment is required. The Enhanced FD/SC is designed so that the operator can replace some modules. Operator maintenance should be a function of the replacement modules stocked by the using unit. MTTR at the Organizational level is based on the time required for an operator to determine a unit is defective and repalce it with a good module from Organizational stocks. The original FD/SC specifications required that the Organizational MTTR be less than fifteen minutes.

However, the maintenance concept formulated for the original FD/SC was based on the replacement of modules at the Intermediate maintenance level. Defective units were to be repaired at the Intermediate level utilizing lowest replaceable items (LRIs) stocked by the activity. MTTR at the intermediate level is currently estimated at less than thirty minutes. MTBF is estimated to be greater than two thousand hours. The contractor's estimates of MTTR anf MTBF

would have to be evaluated during developmental and operational testing.

Ease of Operation: The Enhanced FD/SC's programming uses layering of menus to present information to the operator on the left side of the display panel. After set-up and initialization, the operator is presented with a menu of system functions. When he selects one of the system functions, the Enhanced FD/SC leads him through properly sequenced steps to allow input of all data necessary for the computation. The operator selects a choice from the menu by touching the area of the interactive display panel.

Prompting techniques are used to lead the operator through the sequence of actions he must perform to execute a system function. The operator is able to review and edit his input. The operator directs the Enhanced FD/SC to execute the function. If all the input data is correct, the Enhanced FD/SC performs the computation; otherwise the operator is alerted to an input error. When the computation is complete, the Enhanced FD/SC alerts the operator and displays the output data. The Enhanced FD/SC does not destroy input data. It allows the operator to review input data as well as output data at the completion of computation. Manual and automatic deleting of data are provided to purge unwanted data from the data base. The Enhanced FD/SC provides the operator with an index and allows for the recall of stored data.

The interactive display and a fixed keyboard provide for operator input. The interactive display provides programmable keys (switches, menu items and alternate entry selections). The operator is required to make a selection from the display. Input default selections are provided in the presentation of some menus, so that the operator is not required to make an entry unless his input data is different from the default (normal standard entry).

The fixed keyboard is divided into two major areas: special function and numeric. The fixed keyboard contains thirty-two total keys. The keys are pressure activated and provide a positive feedback to the operator when activated. There are twenty special function keys. Six of the special function keys are currently spares and will be programmed to support the P3I software additions. There are twelve numeric keys (digits, decimal and plus/minus sign). Additionally, the keyboard area contains three trouble indicator lights: Built-in self-test, Low Battery and Power.

Currently all data must be manually inputted by the operator via the fixed keys or interactive menu selection. The first phase of the P3I proposal will enable processing to be initiated by the receipt of messages from external sources over the communications channels. A Call-For-Fire transmitted via the DCT from a Forward Observer will initiate the proper steps to commence processing the fire mission.

A hook capability and graphic cursor are included in the graphics P3I software additions. The Enhanced FD/SC will provide the capability to hook a symbol, thereby identifying it as the point to be effected by subsequent switch actions. The hook symbol is a square designed to enclose the selected graphics symbol. The graphics cursor is a displayed position defined by the operator's finger. The graphics cursor follows the operator's finger until he is satisfied with its position. When the operator removes his finger, the graphics cursor will disappear. When the center of the cursor intersects any part of a symbol or touches a line point, that symbol or line will be hooked and the hook symbol will enclose it. Wearing gloves may require the use of a stylus.

When this author visited Norden Systems on 10 September 1982, the Enhanced FD/SC hardware and software had not been mated. The actual display of information, layering of menus and system operation could not be fully evaluated. In early October 1982 software for the Enhanced FD/SC EDMs was boxed in the actual hardware. Norden Systems should be able to deliver the two Enhanced FD/SC EDMs to the Marine Corps on schedule in March 1983.

Commonality: The Enhanced FD/SC would be a unique Marine Corps system. Norden's GDUs, developed for the BCS, would provide the only real commonality. The technology employed in the development of the Enhanced FD/SC's basic components has surpassed the technology used in the BCS. The

very low degree of commonality creates certain disadvantages. The Enhanced FD/SC would be a Marine Corps unique low density item. The Marine Corps would have to manage the entire maintenance effort. An adequate supply of repair parts would have to be procured to support the Enhanced FD/SC throughout its life cycle. The lack of hardware commonality would most likely result in increased logistics costs. Additionally, the Marine Corps would have to provide for software maintenance.

Norden would have to establish a production line for the Enhanced FD/SC. Initial production line problems associated with any new system would have to be resolved.

Norden has indicated that the Enhanced FD/SC has sufficient growth potential to evolve into a multipurpose lightweight combat terminal. This evolution could be based soley on software modifications. If the Enhanced FD/SC's software is modified for other Marine Corps applications, and the same basic hardware is used, then item density would be increased.

Interoperability: Procurement of the Enhanced FD/SC minimizes the majority of interoperability problems for the battery level fire direction computer system. Norden is developing the Enhanced FD/SC so that it will be able to interoperate with MIFASS, DCT, M90 Velocimeter, AN/TPQ-36 and MDS. The MIFASS interface is no real problem, since Norden is building the MIFASS EDMs. Additionally, Norden is

currently under contract to develop the fire support application software for the Litton DCT. This should greatly simplify the development of the DCT-Enhanced FD/SC interface.

Norden developed the BCS interface for the M90 Velocimeter, AN/TPQ-36 and MDS. These interfaces will be incorporated into the Enhanced FD/SC. The MDS is still under development but no major interoperability problems are anticipated. All of the interfaces will have to be tested as part of the developmental and operational testing. The minimization of the majority of the interoperability problems is a definite advantage of the Enhanced FD/SC.

Procurement Cost: Procurement costs are based on a FY1984 procurement of the Enhanced FD/SC. On 18 November 1982, Norden provided a Rough Order Magnitude Estimate of $50,000 per Enhanced FD/SC to this author [Ref. 42]. This estimate was in current dollars (FY 1983). The cost estimate was converted to FY 1984 dollars using the standard Department of Defense ten percent inflation factor. The FY 1984 production cost for the BCS GDU was used for the Enhanced FD/SC GDU. Table XIII presents Norden's current estimate of the Enhanced FD/SC's procurement cost for an eight gun battery. All costs in Table XIII are in FY 1984 dollars. Norden estimated that the development cost for the additional software to support the P3I would be approximately two million dollars [Ref. 42]. The development cost

is not included in Table XIII. The large amount of software development/programming required for the Enhanced FD/SC introduces a large degree of uncertainty concerning its actual cost. In this author's opinion, the total cost shown in Table XIII is soft.

TABLE XIII

FD/SC Procurement Cost

Item	Cost Per Item	Number Required	Total Cost
FD/SC	$55,000	2	$110,000
GDU	$12,452	8	$ 99,616
			$209,616

D. ALTERNATIVE 4, FIRE CONTROL COMPUTER (FCC)

Litton Data Systems' FCC provides full automated computation, communications and display capabilities for mortars and artillery. It is a hand-held, lightweight, battery powered fire direction computer, capable of rapidly computing ballistic trajectories for the complete inventory of mortars, artillery and ammunition types currently fielded. It combines improvements in the computation of firing data and communications to enhance the overall system's effectiveness.

The FCC has evolved from the Mortar Fire Control Calculator (MFCC) developed by Litton during the mid 1970's. The first feasibility model of the MFCC was produced in 1973. The MFCC was subsequently modified to include the ballistics for artillery weapons. The FCC was developed for and field tested by the United States Army. The Army decided not to procure the FCC.

Litton is currently marketing the FCC as part of a complete battery level fire direction computer system. Litton's system consists of a FCC, Communications Interface Unit (CIU) and GDUs. The FCC and CIU would be located at the battery FDC. The GDUs would be located at the individual weapon locations. Litton has developed the hardware and limited demonstration artillery weaopns programming for the FCC. CIU demonstration hardware has been developed to support a six gun battery. The GDU has only been conceptually defined. For marketing demonstrations Litton is currently using the DCT as a GDU. Litton has not decided whether to design and produce its own GDU or attempt to accquire an existing GDU. Litton has given serious consideration to using the Norden BCS GDU. [Ref. 45]

The FCC is the heart of the Litton battery level fire direction system. It provides the computational capability and basic communication interfaces. The FCC has two communication interfaces: a standard serial interface and a dual purpose communication channel. The FCC serial interface

provides for digital reception/transmission. When used in conjunction with the DCT, the FCC will receive incoming messages, display each on command and perform the required computations. The dual purpose channel provides for digital or voice reception/transmission via wire or radio. The FCC was not originally designed to communicate with GDUs. The CIU was added to allow the FCC to communicate with GDUs.

The CIU is a separate unit which provides for digital or voice transmission of messages via wire or radio to the GDUs. The CIU is in essence a wire line adapter. A radio must be connected to the CIU to complete the radio communications link between the FCC and the GDUs. The CIU also provides a small display which indicates weapon status by target number.

Litton envisions that the GDU will consist of two pieces of equipment per howitzer: a SCA and a GA. The SCA will display Fire Commands and provide for acknowledgement, ready, shot and end of mission reports. The GA will have two displays, one for the gunner with deflection and one for the assistant gunner with quadrant elevation. The GA could be positioned on the ground close to the weapon or mounted on the weapon.

Physical Characteristics: Table XIV provides the general physical characteristics of the FCC. The actual weight of the CIU and GDU has not been determined. The weight of these two items has been estimated in order to

determine an approximate total weight for the complete system. The total weight of the FCC system is based on the equipment required to support an eight gun battery; that is, two FCCs, two CIUs and eight GDUs. The weight of the power cables and the GFE printer is not included.

TABLE XIV

FCC Physical Characteristics

Overall Dimemsions (in.)	FCC 8.6(L), 6.1(W), 1.6(H)
Volume (cu. ft.)	FCC .049
Weight (lbs.)	FCC 3.3, CIU 5.0 SCA 4.0, GA 2.0
Total Weight (lbs.)	63.3
Memory Capacity	144K, 8-bit words
Display	FCC, LED Display, 16 Alpha-numeric characters, approx-imately 3/8 inch in height, 4 pressure sensitive mem-brane switches.
Display Dimensions (in.)	FCC 3 (W), .5 (H)

Litton estimates that prior to production the FCC's memory could be expanded to 288K Bytes. This is based on projected technological advances in the size reduction of memory modules. [Ref. 46]

The display keyboard is 3.375 inches wide and 7.125 inches high. It has forty-eight touch sensitive switches. The size of the actual display area is shown in Table XIII. The display allows for a maximum of sixteen alphanumeric characters. Four pressure sensitive membrane switches overlay the Light Emitting Diode (LED) display. These switches become effective following the activation of an initialization, fire mission or output switch.

Power Requirements: The FCC is powered by one internal non-rechargeable Lithium stick (BA5600/U) battery. The FCC could be modified to use rechargeable batteries. Additionally, a power adaptor allows the use of standard 28 VDC vehicular batteries. The adaptor converts the 28VDC to 8 VDC and acts as a filter for power fluctuations. Another power adaptor allows the use of standard garrison power (60 cycle, 120 volts). No adaptor is available for MEPGSs. [Ref. 46]

The FCC has a power conservation feature. When it is not actually performing one of its specified functions, it will automatically go into a power conserving idle mode. Activation of any touch sensitive switch causes the FCC to return to its normal mode.

Litton estimates that the Lithium stick will provide fifty-three hours of operation under 100 percent continuous operation conditions. "This 53 hours of constant operation is better understood as 30 days of combat operations."

[Ref. 47: p. 25] This estimate was based on normal operation of the FCC given a temperature of 25 Centigrade. The operating life of a Lithium stick varies with temperature. The expected operating time of the Lithium stick battery would be evaluated during developmental and operational testing.

The GDUs would be powered by internal batteries or the vehicular electrical system of self propelled weapons. The type of internal batteries will depend on the final configuration of the GDUs.

Communications Capabilities: The FCC provides for a complete digital fire direction system. The FCC has two communication interfaces: a standard serial interface and a dual purpose communications channel. The serial interface provides for digital reception/transmission via wire or radio. The FCC will receive incoming digital messages, display each on command, and perform the required computation. A message indicator light illuminates when a digital message is received. The FCC can retain three digital messages in the buffer awaiting review by the operator. The message indicator displays the number of messages in the buffer. The digital messages can be formatted or free text. When messages are received digitally, they may be reviewed one line at a time by touching the Message switch, then touching the Sequence switch as required until all lines have been viewed. The Back switch allows previously displayed lines to be reviewed. The serial interface can

also serve as a channel for peripheral units (for example, a printer or the link to MDS).

The dual purpose communications channel provides for digital and voice reception/transmission via wire or radio. Integral standard connectors are provided for the two communication interfaces. Encryption compatibilities include KY 38, KY 57, KG 31 and KG 84 COMSEC systems. The FCC was not originally designed to communicate with GDUs. During the late 1970's consideration was given to locating an FCC at each weapon where it could serve as both a calculator and fire display unit. The CIU was added to allow the FCC to communicate with and drive the GDUs. The CIU is connected to the FCC by wire and serves as a wire line adapter for the GDU wire lines. It provides for digital or voice transmission of messages via wire or radio to the GDUs. A radio must be connected to the CIU to complete the radio communications link between the FCC and the GDUs. The CIU also provides a small display which indicates weapon status by target number.

Programming and Ballistics: The FCC does not require the tape loading of programs. The FCC's firmware will contain the programming for all the required weapon systems and the appropriate projectiles. The ballistic data is contained in the EPROM modules. The current feasibility model of the FCC contains ballistics for the 155mm M109A1, M114A2 and M198 firing the HE family of projectiles.

The FCC does not use the Modified Point Mass Ballistic Model. The FCC uses Litton developed ballistic computation algorithms. Litton's approach uses trajectory interpolation algorithms, as well as new techniques for representing the trajectories, to achieve minimum storage and computation time. The fire control requirements for this model are met with the low cost, single microprocessor which is the heart of Litton's FCC. Litton claims that its approach meets all the stated accuracy requirements.

The FCC firmware would have to be programmed to provide ballistics for all current Marine Corps artillery weapon systems. The FCC can compute individual firing data for eighteen weapon locations. However, it was designed based on a six gun battery. It displays only six individual firing position solutions in sequence. The FCC's programming would have to be significantly modified to properly support the "3 X 8" concept.

Storage Capabilities: Table XV contains the current data base storage capabilities for the FCC. The FCC can determine firing data, store weapon and ammunition information, store and apply Registration Corrections, store fire support coordination measures and apply artillery safety data for the firing position. The FCC has the capability to exchange data bases with another FCC. The FCC storage capacity does not provide for ammunition accounting, retention of fire planning information, and the application of

mask data. Targets and Known Points are stored in the same file. Sixteen locations in this file can be specifically used to store Registration Points.

TABLE XV

FCC Storage Capabilities

Targets/Known Points	66
FO Locations	12
No Fire Areas	10
No Fire Lines	1
Meteorological Files	2
Individual Weapon Locations	18
BTRY or PLT center Locations	3
Concurrent Missions	3
Final Protective Fires (FPFs)	3

Mission Processing: Fire missions can be inputted digitally or manually. The FCC has an automatic computational capability. The Fire Order standards established by the FDO are entered into the FCC as default values. When a fire mission is received via digital transmission from a forward observer, the FCC can automatically compute the firing data. No operator action is required. The firing data is determined based on the established default values and displayed for the operator. However, operator action is required to transmit the Fire Commands to the weapons. The FCC also allows the operator to manually step through a fire mission.

The FCC can process three concurrent fire missions. Table XVI identifies the types of missions that the FCC can be programmed to process. The FCC will process all three methods of target location: grid, polar and shift from a known point. The FCC can also process a laser generated target or projectile point of impact (burst point) information (Slant range, vertical angle and direction) to compute firing data for stationary targets. A special key is provided for laser burst adjustments.

The feasibility model of the FCC only process fire missions which pertain to the HE family of projectiles. The ability to process other families of projectiles/fuzes will be added prior to production in order to meet the requirements of Marine Corps artillery. In processing a nuclear fire mission the FCC would only compute the technical firing data for the nuclear projectile.

TABLE XVI

FCC Mission Processing

Area, Low and High Angle
Registration / Destruction
Illumination / Coordinated Illumination
Air Observer
Laser
Precision Guided munitions (Copperhead)
Nuclear

Auxiliary Functions: The FCC performs a number of auxiliary functions. One of the primary auxiliary functions is the determination of Registration Corrections. The FCC can provide GFT settings for manual back-up. It can determine data for replot. Corrected M90 Velocimeter muzzle velocity readings can be manually inputted. The FCC stores and applies individual weapon muzzle velocities. Comparative VEs must be manually determined. The Comparative VEs are needed to transfer GFT settings.

The FCC alerts the operator when stored fire support coordination measures are violated. In addition the FCC has a feature which provides for the input of artillery safety diagram information (azimuth, minimum and maximum ranges, and charges to be fired). This capability provides for safety control in firing data terms (Deflection, Quadrant Elevation and Charges). The operator is alerted if the fire mission violates the safety diagram input parameters. This feature enhances normal peace time safety procedures and can serve as an additional check for combat operations.

The FCC is programmed to perform basic survey operations. Its capabilities include: Traverse, Intersection and Resection. Additionally, the FCC has the capability to locate a new location based on an azimuth and distance from any known point in the data base.

Maintenance: The FCC contains a built-in self-test for all firmware. The operator performs this test as part of the "preparation for action" sequence. Depressing the key for the test switch activates menus for the self-test of:

1. ROM,
2. RAM,
3. Instruction,
4. Display,
5. Modems, and
6. all switches on the computer.

Operator maintenance is normally limited to: changing the primary battery, keeping the unit clean and running the self-test routines. When the operator runs the self-test and determines that there is a fault in the hardware, the FCC is evacuated to the General Support maintenance activity. Litton envisions that spare FCCs would be maintained in a pool at the General Support Maintenance level. A unit would turn in a faulty FCC and immediately be issued an operational FCC from the pool assets. General Support maintenance is based on the concept of modular replacement.

Maintenance personnel disassemble the FCC, remove the faulty circuit board, solder in a replacement board and reassemble the FCC. The unit is retested with the self-test routines and returned to the operational inventory. MTTR for General Support level repairs is estimated as less 60 minutes. MTBF is estimated at 8800 hours. [Ref. 45] The

contractor's estimates of MTTR and MTBF would have to be evaluated as part of developmental and operational testing.

Circuit boards can be repaired by General Support maintenance personnel. A programmable tester is connected to test points on the faulty circuit board. Then a directed probe is used to isolate the faulty component. The maintenance technician removes the faulty component and solders in a replacement.

Ease of Operation: The front panel and switch processing arrangement of the FCC have been designed to simplify operation. The forty-eight touch sensitive switches are used to execute actions. Several switches lead the operator through the required entries. Prompting sequences are indicated on the display for all applications. The program presents information in menu format to the operator. The display presented to the operator calls attention to the specific data which the program requires the operator to input. Some menus allow input of default values, so that during subsequent operations the operator is not required to make an entry unless his entry is different from the default. The front panel is divided into five major areas:

1. Initialization,
2. LED Display,
3. Execution Switches (including Alphanumerics),
4. Fire Mission, and
5. Output.

For a single step or a series of steps, the display is activated by touching any of the switches in the Initialization, Fire Mission and Output areas of the front panel. The execution switches (including the alphanumerics) and the four switches which overlay the display, become effective following the activation of switches in the other three areas. An attempt has been made to minimize the number of switch positions. Litton's basic design philosophy emphasized that every labeled switch should have only one function.

The sequence switch includes a multidiode indicator which, when lit, informs the operator that there is a multiline block of data for display and selection. When sequencing through these lines of data, the indicator extinguishes upon display of the last line of selectable data.

The four variable switches overlaying the display have associated indicator diodes which, when lit, indicate selectable items from the display. Conversely, if the indicator is not lit, there is no display selection allowable.

The message switch contains indicator diodes which show the operator the number of digital messages stored in the incoming buffer. A low battery indicator is also provided.

The FCC provides an audio and visual alert when a message is received. Additionally, the FCC provides the operator with visual error messages and warnings, when he enters an improper input or any aspect of mission data

violates the established criteria. Currently no audio alert is provided when an error message or warning is displayed. This capability could be programmed into the production model.

This author was able to execute a complete fire mission on the FCC after a fifteen minute overview briefing on the system. The operational sequence was logical and easy to follow. The display is clear and easy to read. The size of the display characters (approximately 3/8 in.) and the use of system prompts contributes to the ease of operation. The operator can adjust the brightness of the display. The addition of the brightness control and improvements in the display membrane cover have enhanced the FCC's display capability. Bright sunlight no longer significantly degrades the LED display. The FCC's field carrying case includes a protective "shade" for the display panel. [Ref. 45]

The FCC uses some mnemonics. Common artillery abbreviations have been used wherever possible. The operator is not required to memorize a large list of new mnemonics. System prompts are used effectively to guide the operator through the mission. The system can be classified as "user friendly". Operation is based on three primary rules:

1. When headings and underlined blank spaces are displayed, use the numeric keyboard to fill in the blanks.

2. When items are displayed from which selection may be made, the display will show up to four selectable items with associated display switch indicators lit. If there are additional items for selection, the Sequence indicator will be lit.

3. When data items are called up for correction or review, the display switch indicators light up for those items which can be selected for correction.

Commonality: The FCC would be a totally unique Marine Corps system. The FCC, CIU and GDUs would all be Marine Corps unique low density items. The Marine Corps would have to manage the entire maintenance effort. An adequate supply of repair parts would have to be procured to support all the items throughout their life cycle. The DCT is very similiar to the FCC in hardware design. Approximately thirty-five percent of the DCT's component parts would be used in the FCC [Ref. 45]. The use of common components provides a limited degree of commonality. In this author's opinion, the low level of hardware commonality would definitely result in increased logistics costs. Additionally, the Marine Corps would have to provide for all of the software maintenance.

Litton would have to establish a production line for the FCC. The initial production line problems associated with any new system would have to be resolved. Litton indicated that the FCC could be produced on the same production line as the DCT. This would reduce some of the initial production line problems. Certain adjustments would have to be made for the differences in case sizes and components.

Interoperability: The FCC minimizes some of the interoperability problems. It will be able to interoperate with the Litton DCT. The DCT is required to interoperate with

MIFASS. Norden is developing the DCT's fire support application software and the complete MIFASS EDMs. As a result, the FCC-MIFASS interface problems should be minimized. The FCC will also be able to interoperate with the Army's TACFIRE, BCS, DMD, and FIST DMD.

The FCC can use the corrected muzzle velocity readings obtained from the M90 Velocimeter. Interfaces for the AN/TPQ-36 and MDS will have to be developed. The MDS is still under development, but no major interoperability problems are anticipated.

All of the interfaces will have to be tested as part of the developmental and operational testing. The minimization of interoperability problems is an advantage of the FCC. However, The FCC's limited communications capability is a drawback to overall interoperability.

Procurement Cost: Procurement cost is based on a FY 1984 procurement of the FCC. Table XVII presents Litton's current estimate of the procurement cost of a FCC battery level fire direction computer system for an eight gun battery. All costs in Table XVII are in FY 1984 dollars. The cost of the FCC includes the CIU. Since Litton has not decided whether to produce its own GDU or accquire an existing GDU, and accurate estimate for the cost of the GDU was not available. However, Litton indicated that the cost of the GDU probably would not exceed the cost of the Norden BCS GDU. Litton is considering purchasing this GDU for use

with its systems. The cost of the GDU in Table XVII is based on the BCS GDU FY 1984 contract option.

TABLE XVII

FCC Procurement Cost

Item	Cost Per Item	Number Required	Total Cost
FCC	$20,000	2	$40,000
GDU	$12,452	8	$99,616
			$139,616

Litton proposes to use a large portion of the existing TACFIRE ballistics software in the FCC. The TACFIRE software would have to be significantly modified to meet Marine Corps requirements and applications. Litton estimated that approximately five hundred thousand dollars would be required for software development/modification [Ref. 45]. This cost is not included in Table XVII. The software development/modifaction and subsequent programming required for the FCC introduces a large degree of uncertainty concerning its actual cost. The GDU cost is in reality a "best guess". In this author's opinion, the total cost shown in Table XVII is very soft. Additionally, the best estimate of IOC for the FCC is FY 1986. This is based on the current status of the DCT and the fact that Litton is considering using the DCT production line for the FCC.

Additional Information: In November 1982, Litton realized that the FCC could not meet the operational requirements listed in the Draft ACS ROC. On 23 November 1982, Litton's Program Manager for Advanced Marine Corps Programs, indicated that an unsolicited proposal for a battery level fire direction computer system consisting of a Lightweight Digital Command Terminal (LDCT), a FCC and GDUs was in the process of being submitted to the Marine Corps. [Ref. 45] The LDCT is a new name for the Litton Briefcase Terminal (BCT). The LDCT is in reality a larger version of the DCT.

Litton envisions the LDCT as the primary computation unit for a "3 X 8" battery. The LDCT would be located in the platoon FDC which was designated as the "primary FDC". The FCC would be used to support the echelon displacement of the firing platoons. Additionally, the FCC would serve as a backup for the LDCT. A CIU is needed for the LDCT and FCC.

This system was demonstrated for this author on 23 November 1982 at the Litton Van Nuys production facility. DCTs were programmed to serve as the GDUs.

This new alternative was proposed too late to be fully researched, documented and evaluated in this thesis. The reader should be aware of this alternative. Litton's unsolicited proposal should contain detailed information regarding the LDCT's technical characteristics. A brief outline of the LDCT is provided for the reader.

The LDCT is a portable, computation and display terminal. The LDCT has an alphanumeric and graphic display. Up to three peripheral devices may be connected simultaneously to the LDCT. These include a map digitzer, typewriter keyboard, printer, and a mass storage device. The LDCT currenlty has a 128K, 16 Bit word memory capacity. Litton estimates that the memory size can be expanded to 512K. It has an LED display overlayed with membrane switches. The LDCT has over 400 programmable and fixed function switches. Six separate radio and wire communications channels are provided. The LDCT is powered by three Lithium stick (BA5600/U) batteries. A power converter allows the use of 28VDC vehicular batteries, MEPGS and standard garrison power. The operation of the LDCT is very similiar to the FCC. The LDCT is interoperable with BCS and TACFIRE. The estimated procurement cost of the LDCT is one hundered thousand dollars [Ref. 45].

E. COMPARISON OF ALTERNATIVES

Table XVIII presents a comparison of the major characteristics of the four alternatives. The characteristics of the Enhanced FD/SC represent its final form upon completion of Norden's P3I proposal. Possible memory expansions are estimates based on plug-in memory modules and technological advances. The MTTR and MTBF are based on contractor estimates. The cost data for the four alternatives listed in

Table XVIII, with the execption of the BCS, are the contractors' best estimates of the procurement cost for a system designed to support an eight gun battery.

The chapter has presented a technical description of four fire direction computer systems which can enhance battery fire direction capabilities. The manufacturers of the systems provided the basic technical data that were presented. Additionally, the chapter provided the manufacturers' current estimate of the procurement cost. The BCS procurement cost was the FY 1984 contract option cost. All cost data were expressed in FY 1984 dollars. The next chapter provides a cost effectiveness analysis of the four alternatives. The analysis uses the data presented in this chapter and previous chapters to measure system effectiveness per dollar of cost for each of the alternatives.

TABLE XVIII

Comparison of Alternatives

Characteristics	ACS	BCS	FD/SC	FCC
Computer Unit Weight (lbs.)	19	90	18.8	3.3
Computer Unit Volume (cu. ft.)	.34	4	.89	.049
Total System Weight (lbs.)	158	634	302	63.3
Memory	256K	128K	720K	144K
Possible Memory Expansion To	304K	None	2000K	288K
Display	Plasma	Plasma	Inter-Act*	LED
Display Area (sq. in.)	24.5	15	46.17**	1.5
Primary Power Source	INT-BAT	VEH-BAT	INT-BAT	INT-BAT
Generator Power	YES	YES	YES	NO
Standard Garrison Power	YES	NO	YES	YES
Dual Purpose Comm-channels	4	2	4**	1
Programming	SC***	TAPE	SC	SC
Ballistics	IMPM#	MPM##	IMPM**	LITTON
Graphics	NO	NO	YES**	NO
MTTR (min.)	10	30	20	60
MTBF (hrs.)	1500	1200	2000	8800
Total Cost Per Battery	$102,000	$339,860	$209,616	$139.616

See notes next page.

Notes:

* Plasma overlayed with an Interactive Device

** Based on the P3I proposal

*** Self Contained in memory

\# Improved Modified Point Mass

\#\# Modified Point Mass

VI. ANALYSIS

A. DEFINITION OF THE PROBLEM

The Marine Corps current battery level fire direction systems are inadequate to meet the demands of today's battlefield.

B. OBJECTIVE OF ANALYSIS

The objective of this analysis is to determine which battery level fire direction computer system the Marine Corps should procure.

C. DESCRIPTION OF ALTERNATIVES

This analysis evaluates four alternatives which are currently considered to be the prime candidates for replacing the existing battery fire direction systems. In alphabetical order the four alternatives are:

1. Alternative 1, Artillery Computer System (ACS)
2. Alternative 2, Battery Computer System (BCS)
3. Alternative 3, Enhanced Fire Direction/Survey Calculator (FD/SC)
4. Alternative 4, Fire Control Computer (FCC)

A complete technical description of the four alternatives was presented in Chapter Five. A number of other alternatives in various stages of design/development are currently being marketed by American and foreign companies. It was beyond the scope of this thesis to consider all the available fire direction computer systems. Preliminary analysis was used to narrow the alternatives to the four listed above, so that a complete analysis of the most promising alternatives could be conducted.

D. CRITERION

A benefit-cost approach was selected as the criterion for comparing alternatives. The four alternatives have unequal benefits and unequal costs. A combat effectiveness index is used to measure the benefit of each alternative. The combat effectiveness index is based on a subjective assessment of each alternative's contribution to an artillery battery's combat effectiveness. The estimated procurement cost for each alternative is used as the measure of cost. The procurement cost is based on the equipment required to support an eight gun battery. A benefit-cost ratio for an artillery battery is developed. The ratio of the combat effectiveness index to the estimated procurement cost is used to determine the optimal battery level fire direction computer system.

E. ASSUMPTIONS

Constant dollars: The alternatives are analyzed in terms of FY 1984 dollars. Procurement costs are based on an FY 1984 production.

Accurate Cost Estimates: The BCS cost data are based on the existing Army contract. The FY 1984 contract option costs are used in the analysis. The cost estimates for the ACS, Enhanced FD/SC and FCC were provided by the manufacturers. The alternatives are analyzed based on the cost data presented in Chapter Five. It is assumed that the manufacturers have provided accurate estimates of the procurement cost.

Accurate Technical Data: The alternatives are analyzed based on the technical data presented in Chapter Five. It is assumed that the technical data is correct. It is recognized that certain system features may change as development progresses.

Economic Life: All alternatives are assumed to have the same economic life.

Introduction of the "3 X 8" Concept: The alternatives are analyzed in terms of the planned reorganization of Marine artillery and the implementation of the "3 X 8" concept in the Direct Support artillery battalions. Additionally, it is planned that an eight gun battery will have two platoon FDCs, each equipped with a computer unit.

F. EFFECTIVENESS

1. Effectiveness Model

Top level acquisition decisions are complex and multi-objective. This implies difficulties in appropriately accounting for all relevant factors to select the best alternative. Multi-Attribute Utility Theory (MAUT) is a technique which allows the decision-maker to evaluate two or more alternatives whose utility varies along several dimensions of value. MAUT is essentially a descriptive technique that processes information according to specific rules. Data processing is accomplished within a logical but flexible framework founded upon quantitative combinations of evidence. Evidence is brought to bear on the alternatives to be evaluated by locating them on various dimensions of value. The located measures are then aggregated according to a combination rule which weighs the relative importance of each dimension. If the model is successful, it will identify the alternative that represents the greatest worth to the decision-maker. [Ref. 48: p. 66] Decisions With Multiple Objectives, [Ref. 49] presents a complete description of MAUT.

An application of MAUT is used to determine a combat effectiveness index for an artillery battery. This index represents the measure of effectiveness for each alternative, as a function of the author's opinions. The following

seven steps were used to determine the combat effectiveness index for each alternative.

a. The major attributes of fire direction computer systems which contribute to the enhancement of an artillery battery's combat effectiveness were identified.

b. These attributes were subjectively ranked in order of importance based on their individual contribution to an artillery battery's combat effectiveness.

c. The four alternatives were rated for each attribute. Ratings of Below Average, Average, and Above Average were subjectively assigned to each alternative.

d. The attributes were weighted. Weights were assigned based on subjective judgement. A total of two hundred weights was allocated among the attributes.

e. The descriptive alternative ratings were replaced by a numerical value. The assigned value represents the relative positioning of Below Average, Average, and Above Average ratings on a scale of one to ten. A value of three represents Below Average, a value of five represents Average, and a value of seven represents Above Average.

f. The attribute weight was multiplied by the respective numerical value for each alternative.

g. The alternative's combat effectiveness index is the summation of the individual attribute weight multiplied by the respective numerical value for all the identified attributes.

2. Determination of Effectiveness

Data from the questionnaires and numerous interviews with artillery commanders, combined with this author's previous artillery experience, assisted in identifying the attributes of a fire direction computer system which can significantly enhance an artillery battery's combat

effectiveness. Ten major attributes were selected based on this author's understanding of artillery fire direction procedures. These ten attributes are listed and discussed in alphabetical order.

Communications Capability: This attribute addresses the system's external and internal communications capabilities. The Gunnery Team is linked by communications. Improvements in the voice or digital transmission of Calls-For-Fire and Fire Commands will increase system response time.

Ease of Operation: The computer should be "user friendly". System prompts should be used to assist the operator. Alerts should be provided when erroneous data are entered into the computer. A computer system which is relatively easy to operate minimizes the operator training requirements. A "user friendly" system allows the operator to gain confidence in his ability to use the system. A system which is relatively simple to operate is essential under the stress imposed by combat operations.

Growth Potential: This attribute addresses the system's potential for additional growth. A fire direction computer system must have sufficient memory and computational power to provide for the incorporation of future improvements in the field artillery system. The system should be capable of evolving over its life span to meet new demands.

Gun Display: The visual display of Fire Commands to the section chief, gunner and assistant gunner will increase system response time.

Interoperability: This attribute is concerned with the system's capability to interoperate with existing systems and systems currently under development. A battery level fire direction computer must be capable of receiving and utilizing input from the DCT, MDS, AN/TPQ-36 and MIFASS. Interoperability requirements for the system should be based on an automated assisted interface.

Maintainability: It is important here to distinguish between maintainability and maintenance. Maintainability is defined as a characteristic of design and installation which is expressed as the probability that an item will be retained in, or restored to, a specified condition within a period of time when maintenance is performed in accordance with prescribed procedures. Maintenance is the set of actions necessary for retaining an item in, or restoring it to, a specified condition. Thus maintainability is a system design parameter while maintenance actions are a result of the system's design. The purpose of maintainability is to provide the required availability and dependability by maximizing ease of maintenance in a manner that is consistent with other system requirements and by minimizing support resources required.

Mission Processing/Programming: This attribute addresses the system's ability to process the various types of artillery fire missions and the programming required to support the execution of these missions. Programming must provide for the responsive and accurate computation of firing data. The effectiveness of artillery fire support is significantly increased by the timely and accurate computation of individual weapon to aimpoint ballistic solutions which account for all non-standard conditions.

Power Source: The capability of a fire direction computer system to operate from various types of power sources provides a degree of flexibility to the users.

Reliability: The probability that an item will perform its intended function for a specified interval under stated conditions. The reliability of a system depends on its design. Additionally, the manufacturer's quality assurance program becomes a key factor in assuring that the reliability inherent in the final design is not compromised in the manufacturing process. A highly reliable fire direction computer system will require far less support and will provide the means for reaching vital levels of combat effectiveness while holding the line on life cycle cost. A system that consistently performs will be used by the operators.

Size and Weight: Transportability, installation and system operation are effected by the system's physical characteristics. This attribute addresses the size and

weight of the system's components, total system weight and volume.

a. Ranking of Attributes

The ten major attributes were subjectively ranked in order of importance based on their individual contribution to an artillery battery's combat effectiveness. Table XIX presents the ranking of the attributes.

TABLE XIX

Ranking of Attributes

Reliability
Ease of Operation
Maintainability
Communications Capability
Gun Display
Interoperability
Mission Processing/Programming
Growth Potential
Power Source
Size and Weight

Reliability was ranked as the most important contributor to combat effectiveness. The responses to the questionnaires clearly emphasized the importance of reliability. If a system is not working it cannot contribute to effectiveness.

Ease of Operation was ranked as the second most important attribute. The full potential of any computer

system can only be attained when the operator is confident of his ability to use the system. The best computer in the world will not enhance combat effectiveness if the operator has difficulty performing the required system actions. The fire direction computer system must be designed to be "user friendly", since the operator will have to use the system during combat operations. Simple procedures provide the best results.

The questionnaires indicated that the system should be maintainable at the Organizational level. When the system fails, maintenance actions should be able to quickly restore the system to normal operation. System downtime must be minimized.

The Communications Capability was ranked higher than Gun Display and Interoperability. These latter two attributes depend on the system's overall communications capability. The best Gun Display Units are ineffective without a proper communications channel. Communicatons link the widely separated elements of the Gunnery Team.

Interoperability at the battery level centers on the system's ability to interface with the DCT, MDS, AN/TPQ-36, and MTFASS. Firing batteries are concerned with the execution of fire missions. The importance of interoperability increases at higher echelons of command.

Mission Processing/Programming provides a greater contribution to combat effectiveness than growth

potential. A battery fire direction system should have some growth potential. This allows for flexibility and future applications. However, programming is required to transform potential into reality. Tremendous growth potential without proper programming does not immediately contribute to combat effectiveness.

The ability to operate from various power sources is more important than the size and weight of the system. Battery power frees the unit from relying on generator power in fast moving situations. Generators can provide power to sustain continuous operations in a relatively static environment.

b. Rating of Alternatives

The four alternatives were subjectively rated for each attribute. Ratings of Below Average (BA), Average (A), and Above Average (AA) were assigned. The ratings were determined based on the data presented in Chapter Five. Table XX provides the ratings that were assigned.

The reliability rating considers more than the contractor's estimate of MTBF. The reliability of the BCS and ACS was rated above average. The BCS rating was based on the final operational test results and comments of artillery officers stationed at Fort Sill. The ACS rating was based on the limited developmental test results of the FIST DMD and Magnavox's well-defined quality assurance program. This

TABLE XX

Rating of Alternatives

Attribute	ACS	BCS	FD/SC	FCC
Reliability	AA	AA	A	A
Ease of Operation	AA	BA	A	A
Maintainability	A	AA	A	BA
Commo Capability	AA	BA	A	BA
Gun Display	A	AA	AA	BA
Interoperability	A	AA	AA	BA
Msn Pro/Programming	AA	A	A	BA
Growth Potential	A	BA	AA	BA
Power Source	AA	A	A	BA
Size and Weight	AA	BA	A	AA

author was impressed by the quality assurance program that Magnavox has established for the DMD and FIST DMD production line. The ACS is a derivative of these systems and it will be manufactured on the same production line. The MTBF for the BCS and ACS are considered to be good estimates. The Enhanced FD/SC reliability has not really been demonstrated. The system was only boxed in its hardware in early October. The FCC demonstration models have never achieved the stated MTBF. The reliability of the FCC alternative was rated average because the entire system has not really been

finalized. The high MTBF for the Enhanced FD/SC and FCC has not been clearly established.

The ACS was rated above average for ease of operation. THe system prompts and layering of menus provided a logical step by step process. The ACS is a "user friendly" system. The BCS was rated below average, because of the requirement to learn an excessive amount of new mnemonics. A BCS operator needs at least eighty hours of instruction to be able to operate the system with limited proficiency. The Enhanced FD/SC and FCC were rated average. The menu layering in the FCC is not as efficient as the layering in the ACS.

The BCS was rated above average for maintainability. This rating was based on the excellent built-in self-test routines, MTTR, and ease of maintenance. The ACS and Enhanced FD/SC were rated average. Their MTTR estimates have not been validated by actual field testing. The FCC was rated below average, because all maintenance must be performed at the General Support level.

The ACS has superior communications capability. The Enhanced FD/SC communications capability is based on the completion of the P3I. The Enhanced FD/SC EMDs which will be delivered to the Marine Corps in March 1983 will have only one communications channel. This channel will provide for the GDU communications link. The BCS and FCC have limited communications capabilities.

The Norden GDU for the BCS and Enhanced FD/SC was rated above average, because it is the only fielded GDU. The Norden GDU has been extensively tested by the U.S. Army. The problems identified during operational testing have been corrected. The Magnavox GDU is smaller and lighter but it has not been tested during actual firing. The FCC GDU has only been conceptually defined. If Litton uses the Norden GDU, interface problems will still have to be resolved. The FCC GDU capability was rated below average.

Interoperability was rated above average for the Enhanced FD/SC and BCS. Since Norden is developing the MIFASS EDMs and the software fire support application programs for the DCT, interoperability problems would be minimized. The interoperability capabilities of the Enhanced FD/SC will exceed those of the BCS. The ACS interoperability was rated average. The FCC interoperability was rated below average. Its limited communications capability affects interoperability.

The Mission Processing and Programming of the ACS was rated above average. The ACS has mission processing capabilities which are similar to BCS. The ACS incorporates the Improved Modified Point Mass Ballistic Model. It can compute firing data for sixteen individual weapon locations; whereas, the BCS can compute firing data for twelve individual weapon locations. The BCS is the only tape loading alternative. The BCS and Enhanced FD/SC were rated average

based on the mission processing capabilities and programming presented in Chapter Five. The FCC was rated below average. The FCC uses the Litton developed ballistic model. It was designed to support a six gun battery. Modifying the FCC to handle eight guns would require major software changes.

The FD/SC has excellent growth potential. The total growth potential for the Enhanced FD/SC is based upon completion of the P3I proposal. The Enhanced FD/SC has the potential to evolve into a multipurpose lightweight combat terminal. It currently has a very impressive memory capability. The Enhanced FD/SC will provide a graphics capability. The growth potential of the ACS was rated average. The BCS and FCC were rated below average. The BCS memory size is fixed and would require a significant investment to expand this capability through an unplanned product improvement. The FCC is in reality a very powerful calculator. It does not have the capability to evolve into a multipurpose combat terminal.

The ACS and Enhanced FD/SC can operate from a large variety of power sources. This provides the commander with a large degree of flexibility. The ACS uses fewer internal batteries than the Enhanced FD/SC. The ACS was rated above average and the Enhanced FD/SC was rated average. The BCS cannot operate from internal batteries and requires a power disrtibution unit. The BCS GDUs include an internal battery power option. The BCS was rated average.

The FCC power sources are limited. The inability of the FCC to operate directly from MEPGS is a major disadvantage. Therefore, it was rated below average.

The size and weight of the ACS and FCC were rated above average. When all components are considered, the Enhanced FD/SC is twice as heavy as the ACS and the BCS is four times heavier than the ACS. The BCS is large and bulky. It is primarily suited for installation in a vehicle. The BCS was rated below average.

c. Weighting of Attributes

Table XXI presents the weights that were subjectively assigned to each attribute. Weight assignment was based on information gained from the overall research effort for this thesis and this author's previous artillery experience. Any number of different weighting scales could have been used. The weighting scale should allow for a sufficient spread between the various attributes. This thesis uses a two hundred point weighting scale. A total of two hundred weighting points was allocated among the various attributes. Assignment proceeded from the lowest ranking attribute to the highest ranking attribute. This type of weighting system permits ties between attributes. However, in the assignment of weights no ties occurred. All weights were expressed as whole numbers.

TABLE XXI

Weighting of Attributes

Attributes	Weight
Reliability	35
Ease of Operation	30
Maintainability	28
Commc Capability	25
Gun Display	22
Interoperability	20
Msn Pro/Programming	15
Growth Potential	12
Power Source	8
Size and Weight	5
Total Weights	200

d. Assignment of Numerical Values

The descriptive alternative ratings were replaced by numerical values. Any scale which provides a consistent spread between the three descriptive ratings can be used. A scale of one to ten was used to transform the descriptive rating into a numerical value. A value of three represents below average, a value of five represents average, and a value of seven represents above average. The average value (5) is the numerical average of the values assigned to below average and above average. Table XXII

depicts the replacement of descriptive ratings with numerical values. Additionally, the weight assigned to each attribute is indicated.

TABLE XXII

Assignment of Numerical Values to Alternatives

Attribute	Weight	ACS	BCS	FD/SC	FCC
Reliability	35	7	7	5	5
Ease of Operation	30	7	3	5	5
Maintainability	28	5	7	5	3
Commo Capability	25	7	3	5	3
Gun Display	22	5	7	7	3
Interoperability	20	5	7	7	3
Msn Pro/Programming	15	7	5	5	3
Growth Potentail	12	5	3	7	3
Power Source	8	7	5	5	3
Size and Weight	5	7	3	5	7

e. Measure of Effectiveness

Table XXIII presents the determination of the combat effectiveness index for each alternative. The attribute weight was multiplied by the respective numerical value for each alternative. The alternative's combat effectiveness

TABLE XXIII

Combat Effectiveness Index

Attribute	ACS	BCS	FD/SC	FCC
Reliability	245	245	175	175
Ease of Operation	210	90	150	150
Maintainability	140	196	140	84
Commo Capability	175	75	125	75
Gun Display	110	154	154	66
Interoperability	110	140	140	60
Msn Pro/Programming	105	75	75	45
Growth Potential	60	36	84	36
Power Source	56	40	40	24
Size and Weight	35	15	25	35
Total, Combat Effectiveness Index	1246	1066	1108	750

index is the summation of the values shown in each column of Table XXIII. This combat effectiveness index is the measure of effectiveness which represents the relative benefit of each alternative.

G. COST MODEL

All of the alternatives have significantly different costs. In a cost effectiveness analysis, the cost model

should be based on the life cycle cost for each alternative. However, the BCS is the only alternative for which an accurate estimate of life cycle cost exists. It was beyond the capabilities of this author to develop accurate estimates of life cycle cost for the other three alternatives in the short time span available for the completion of this thesis. Therefore, the estimated procurement cost of each alternative based on an FY 1984 production was selected as the measure of cost. Table XXIV presents the procurement cost per artillery battery for each alternative. The procurement cost is based on the equipment required to support an eight gun artillery battery. This includes two computer units and eight GDUs. All costs in Table XXIV are in FY 1984 dollars.

TABLE XXIV

Procurement Cost Per Artillery Battery

System	ACS	BCS	FD/SC	FCC
Cost	$102,000	$339,860	$209,616	$139,616

In this author's opinion the procurement costs for the Enhanced FD/SC and the FCC are soft. These systems require additional research and development funds for software. A discussion of additional requirements was presented in Chapter Five. Norden's cost estimate of the P3I proposal

must be viewed as a "best guess". Software cost and development schedules have been traditionally understated. The majority of any computer system's total cost is based on the software cost. The actual hardware only represents a small fraction of the total cost.

> Software is the most unsafe, the least understood, and the most expensive component of total computer system costs. Software development costs are now almost 90 percent of total computer system costs. This percentage will probably increase along with the absolute costs of software, since software design, development and testing (are) the most highly labor-intensive component (s) of computer system products. The cost of software has risen continuously. Overruns of 100 percent in both cost and the time to develop software have not been unusual occurrences. In fact, there have been cases of total failure to develop systems due to software cost and schedule overruns. [Ref. 50: p. 19]

The U.S. Army currently plans to maintain the BCS well into the 1990's [Ref. 41]. Selection of the ACS, Enhanced FD/SC or FCC establishes a totally unique Marine Corps battery level fire direction computer system. The Marine Corps would be completely responsible for the life cycle maintenance and training costs of the ACS, Enhanced FD/SC and FCC. It should be noted that these three unique alternatives significantly impact on life cycle support costs.

In this author's opinion software maintenance of these three alternatives will be a very significant cost. It is impossible to accurately estimate the software maintenance costs of systems which have not even been operationally tested. The estimates of any required software maintenance made after operational testing is complete will most likely

be very soft. However, past experience in the development of computer systems can provide a rough approximation of software maintenance costs. "The cost of maintaining software is estimated to account for 75 percent of all software costs." [Ref. 50: p. 19]

In this author's opinion, the life cycle training cost for the ACS, Enhanced FD/SC and FCC would be roughly equivalent. However, a significant difference between these three alternatives and BCS emerges. The Marine Corps would have to procure a sufficient number of systems to provide for any formal school training. A completely unique training program would have to be developed.

The high procurement cost of the BCS may offset any life cycle cost savings in maintenance and training. It is recognized that there are most likely differences in the total life cycle costs of the four alternatives. Life cycle cost data would provide the best measure of system cost for a cost effectiveness analysis. Since these data were neither available nor could they be accurately estimated, procurement cost was used as a proxy to measure system cost.

H. BENEFIT-COST

1. Ranking of Alternatives

The ranking of alternatives is presented in Table XXV. The ranking is based on the determination of a

benefit-cost ratio for the equipment required to support an eight gun artillery battery. The benefit is expressed in terms of the combat effectiveness index (CEI). This index was developed in Table XXIII. The cost is the estimated system procurement cost per artillery battery in FY 1984 dollars. This cost has been expressed in thousands of dollars. The ratio of the combat effectiveness index to the estimated procurement cost is used to determine the optimal battery level fire direction computer system. The ACS provides the greatest benefit per dollar of cost.

TABLE XXV

Ranking of Alternatives

Alternative	CEI	Cost ($000)	Ratio
ACS	1246	$102.000	12.22
FCC	750	$139.616	5.37
Enhanced FD/SC	1108	$209.616	5.29
BCS	1066	$339.860	3.14

2. Sensitivity Analysis

The analysis in this thesis assumes unequal benefits and unequal costs for the alternatives. The benefits were subjectively determined and the costs for three of the four

alternatives were based on manufacturers' estimates of procurement cost. Based on equal benefits and the existing estimated procurement costs, the ACS still provides the largest benefit-cost ratio.

Since effectiveness was determined subjectively, different artillerymen would most likely determine different totals for the combat effectiveness index. If this author's determination of the combat effectiveness index is assumed to be reasonable correct and the system cost is changed, then the sensitivity of the alternatives can be further examined. The BCS procurement cost is fixed by the FY 1984 contract option. The other costs will most probably increase as system development progresses. A 100 percent increase in the estimated procurement cost of the ACS provides a 6.11 benefit-cost ratio. Therefore, if the ACS procurement cost is assumed to increase by 100 percent and the estimated procurement costs of all the other alternatives remain unchanged, the ranking of alternatives presented in Table XXV will not change.

Table XXVI presents the ranking of alternatives based on a 100 percent increase in the procurement cost of the ACS, a 50 percent increase in the procurement cost of the Enhanced FD/SC and FCC, and an unchanged BCS procurement cost. The ranking of the alternatives remains unchanged. In this author's opinion a 100 percent increase in the procurement cost of the ACS is highly unlikely. The ranking of the

alternatives was not affected by sizeable percentage changes in the system procurement cost while holding the determined effectiveness constant. The ACS consistently produces the largest benefit-cost ratio.

TABLE XXVI

Ranking Based on Increases in Procurement Cost

Alternative	CEI	Cost ($000)	Ratio
ACS	1246	$204.000	6.11
FCC	750	$209.424	3.58
Enhanced FD/SC	1108	$314.424	3.52
BCS	1066	$339.860	3.14

This chapter has presented a cost effectiveness analysis of the four alternatives discussed in Chapter Five. The final chapter provides the conclusions and recommendations of this thesis.

VII. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

Artillery is the MAGTF Commander's primary all-weather fire support asset. Today's battlefield scenarios demand that artillery fire support must be responsive, accurate and effective. The majority of Marine Corps artillery units currently compute firing data using antiquated manual procedures. In an age of significant technological advances in computation and automatic data processing systems, the Marine Corps still utilizes a manual system consisting of paper firing charts, plotting pins and GFTs. FADAC, fielded during the mid 1960's, is also outmoded and beyond its expected service life. FADAC is not being used and cannot be relied upon. The PRHC has only limited capabilities. It cannot support extended combat operations. Simply stated, the current Marine artillery fire direction systems are inadequate to meet the demands of today's battlefield. The lack of a modern artillery fire direction computer system degrades the Marine Coprs overall combat effectiveness.

Since the late 1960's the Marine Corps and the Army have been moving toward the establishment of two unique fire support/fire direction systems, MIFASS and TACFIRE. Many Marines have not realized this, because TACFIRE has only

recently been fielded and MIFASS is still under development. MIFASS is being designed to complement the Marine Corps concept of operations. The two systems support the unique requirements of each service. It is important to understand that in the near future two completely different, but interoperable, systems will exist.

The field deployment of MIFASS is at least five years in the future. MIFASS will provide the artillery battalion FDC with a state-of-the-art fire support/fire direction computer system. However, MIFASS, as presently configured, does not extend to the battery level. MIFASS will not resolve the fire direction problem at the battery level. The artillery battery needs an automated computational capability to support autonomous battery operations. The fire direction problem is especially critical at the battery level and needs to be expeditously resolved. The Marine Corps faces a critical window of vulnerability until the complete fire direction problem is solved.

Responses to the questionnaires clearly establish that the artillery regiments emphasize different methods for computing firing data. Marine artillery does not have a "standard" primary method for determining firing data. The active artillery units are using the PHHC. Approximately 36 percent of the artillery batteries in the active force structure use the PHHC as the primary means for determining firing data. The reserves are not using the PHHC. FADAC

maintenance support is inadequate. Based on the data provided by the questionnaires, the average FADAC downtime exceeds sixty days. FADAC maintenance support problems will continue to increase.

Research for this thesis indicates that the impact of the "3 X 8" concept has not been fully addressed by the Marine Corps. The Marine Corps Development and Education Command's Doctrine Department, Firepower Division and the Command Control and Communications Division (C3) could not provide definitive information regarding the organization of the fire direction system, number of personnel required to support an FDC equipped with a new battery computer system, and the concept of employment. The 3 X 8 concept introduces a myriad of additional problems for Marine artillery. These problems can be resolved. Data from the questionnaires indicates that two platoon FDCs each equipped with a computer unit are required to adequately support the employment of an eight gun battery.

Since its inception, the ACS program has been poorly managed. This is not meant to be an indictment of any individual or group of individuals. The acquisition strategy has clearly violated a number of the Department of Defense acquisition principles. The documentation for the ACS program is incomplete and disorganized. The ACS is currently approaching OT II without the publication of an approved ROC. The development of the ACS has been degraded by the

parochial interests of a number of different Marine Corps activities and agencies. These activities and agencies have placed their parochial interests above the needs of the Marine Corps.

In September 1980 an article in the Marine Corps Gazette clearly identified the organizational weakness which, to this day, still continues to affect Marine artillery, "namely the lack of focus, or single head". [Ref. 7: p. 65] The author of this article depicted the community of commands and agencies in the Marine Corps involved with artillery doctrine, tactics, techniques and development as a "Hydra like creature". Two years later the "Hydra" is alive and growing. Without definitive direction provided by a single head, the parochial interests of the individual activities and agencies will continue to dominate.

Marine artillery needs a fire direction computer system to replace FADAC at the battalion and battery level. A FADAC replacement is needed now, not later. MIFASS is supposed to provide the artillery battalion with an automated fire support/fire direction capability. ACS is supposed to be a battery level fire direction computer system. However, a careful examination of the Proposed ROC for the ACS reveals that the design parameters address a system capable of functioning at the battery and battalion levels. It is a classic example of acquiring a system that is really needed and desired under an "accepted name".

If the ACS is fielded in FY 1985 as a battery level fire direction system and the MIFASS IOC continues to slip, then an intolerable situation will result. The artillery batteries will have a fire direction capability that is far superior to the battalion FDC's existing capability. The battalion FDC will have to continue to rely on FADAC and the PHHC. The artillery battalion FDC cannot be cut out of the fire direction loop. Artillery battalions, not batteries, provide the effective massed fire support that is essential for success in combat.

The cost effectiveness analysis presented in Chapter Six determined that the Magnavox ACS is the optimal battery level fire direction computer system. It provides the greatest benefit per dollar of cost. The ranking of the alternatives was not affected by sizeable percentage changes in the system procurement cost. The ACS consistently produced the largest benefit-cost ratio. The ACS can provide a significant enhancement in an artillery battery's combat effectiveness.

The total procurement cost for the ACS is relatively inexpensive when one considers the benefits and compares it to the cost of other new systems. If 200 complete sets of ACS equipment were purchased at a cost of $102,000 per set, the total procurement cost is 20.4 million dollars (FY 1984 dollars). Compare this cost to the flyaway cost of an F-18 or AV-8B aircraft. The flyaway cost of a single F-18 is

currently estimated to be approximately 22.775 million dollars (FY 1982 dollars). The flyaway cost of a single AV-8B is currenlty estimated to be approximately 21.58 million dollars (FY 1982 dollars). The aircraft flyaway cost figures were extracted from the 30 September 1982 Department of Defense Selected Acquisition Report (SAR). [Ref. 51] The ACS will provide a significantly greater increase in overall Marine Corps combat effectiveness than any single fixed wing airframe. Artillery remains the primary fire support asset for the MAGTF. Marine artillerymen must be given a computational capability to ensure that fire support is responsive, accurate and effective.

B. RECOMMENDATIONS

The objective of this research effort has been to determine which battery level fire direction system the Marine Corps should procure. While motivated by personal experiences in previous artillery assignments, individual bias was, hopefully, not a significant factor in the determination of direction or outcome of the analysis. Based on this research effort a number of specific recommendations have been compiled. These recommendations should not be construed as representing the totality of actions needed to solve the artillery fire direction problem. Instead, they are simply representative of the types of action which should assist in the resolution of the artillery fire direction problem.

1. That the Marine Corps adopt and publish a ROC for the Artillery Computer System (ACS).

2. That the Marine Corps review, correct and update the complete ACS acquisition documentation.

3. That the Marine Corps adopt the ACS, provided that the initial operational test scheduled for January 1983 is satisfactory.

4. That the Marine Corps adapt the ACS for use as a battalion level fire direction computer system on an interim basis until the introduction of MIFASS.

5. That the Marine Corps revaluate the Letter of Adoption and Procurement for the ACS.

6. That the Marine Corps assign a professionally competent artilleryman to Magnavox, as an in-plant representative, to assist in the development of the ACS.

7. That, once a final acquisition decision is made, the Marine Corps develop a complete system introduction plan for the ACS. This plan must be carefully developed to ensure that organizational resistance to change is minimized.

8. That the Marine Corps establish a formal training course for ACS operators at the U.S. Army Field Artillery School and that sufficient assets (computers, gun display units and instructors) be provided.

9. That the Marine Corps plan to contract for the ACS life cycle software support.

10. That the Marine Corps adopt the ACS as the "primary method" for determining firing data and that the MCCRES standards for artillery units be based on the ACS's capabilities.

11. That the Marine Corps emphasize the use of FADAC in the battalion/alternate battalion FDCs until ACS is fielded. Thses FDCs can make excellent use of FADAC capabilities for data update.

12. That the Marine Corps emphasize the use of the PHHC in the battery FDCs until ACS is fielded.

13. That the Marine Corps closely monitor FADAC supportability. FADAC assets should be redistributed, if required, to maintain a balanced capability in the different artillery regiments.

14. That the Marine Corps address the total impact of the "3 X 8" concept.

15. That the Marine Corps expand the PHHC operator instruction at the U.S. Army Field Artillery School until the ACS is fielded.

16. That the Marine Corps consider an organizational change to create a single head for Marine artillery

who can formulate, review and evaluate artillery system acquisitions, doctrine, tactics, and techniques.

The time has come for Marine artillery to break out of its conservative, staid approach toward change. The time for change and system improvement in artillery fire direction is now. An artillery fire direction computer system is needed today, not tomorrow. The needs of the Marine Corps and the nation demand it. Effective and efficient utilization of artillery fire support assets require it. The adoption of the Artillery Computer System will enhance overall Marine Corps combat effectiveness.

APPENDIX A

LIST OF ABBREVIATIONS

ACS	Artillery Computer System
ACU	Artillery Computer Unit
ADAM	Area Denial Artillery Munition
ADM	Acquisition Decision Memorandum
ADO	Advance Development Order
ADP	Automatic Data Processing
APM	Arithmetic Processing Memory
ARRCOM	Armament Readiness Command
BCS	Battery Computer System
BCT	Briefcase Terminal
BCU	Battery Computer Unit
BDU	Battery Display Unit
CECOM	Communications and Electronics Command
CEI	Combat Effectiveness Index
CFF	Call For Fire
CIU	Communications Interface Unit
CMD	Communications Message Device
COMSEC	Communications Security
CP	Command Post
CP MSN	Copperhead Priority Mission
C3	Command Control and Communications
DASC	Direct Air Support Center
DC	Direct Current

DCT	Digital Communications Terminal
DMD	Digital Message Device
DPICM	Dual Purpose Improved Conventional Munition
DS	Direct Support
ECP	Engineering Change Proposal
EDM	Engineering Development Model
EPROM	Electrically Programmable Read Only Memory
FADAC	Field Artillery Automatic Digital Computer
FASCAM	Family of Scatterable Mines
FCC	Fire Control Computer
FD/SC	Fire Direction / Survey Calculator
FDC	Fire Direction Center
FDO	Fire Direction Officer
FIST DMD	Fire Support Team Digital Message Device
FM	Field Manual
FMFM	Fleet Marine Force Manual
FO	Forward Observer
FPF	Final Protective Fire
FSCC	Fire Support Coordination Center
GA	Gun Assembly
GCI	Gun Control Interface
GCU	Gun Control Unit
GDU	Gun Display Unit
GFE	Government Furnished Equipment
GFT	Graphical Firing Table
GLLD	Ground Locator Laser Designator
GS	General Support

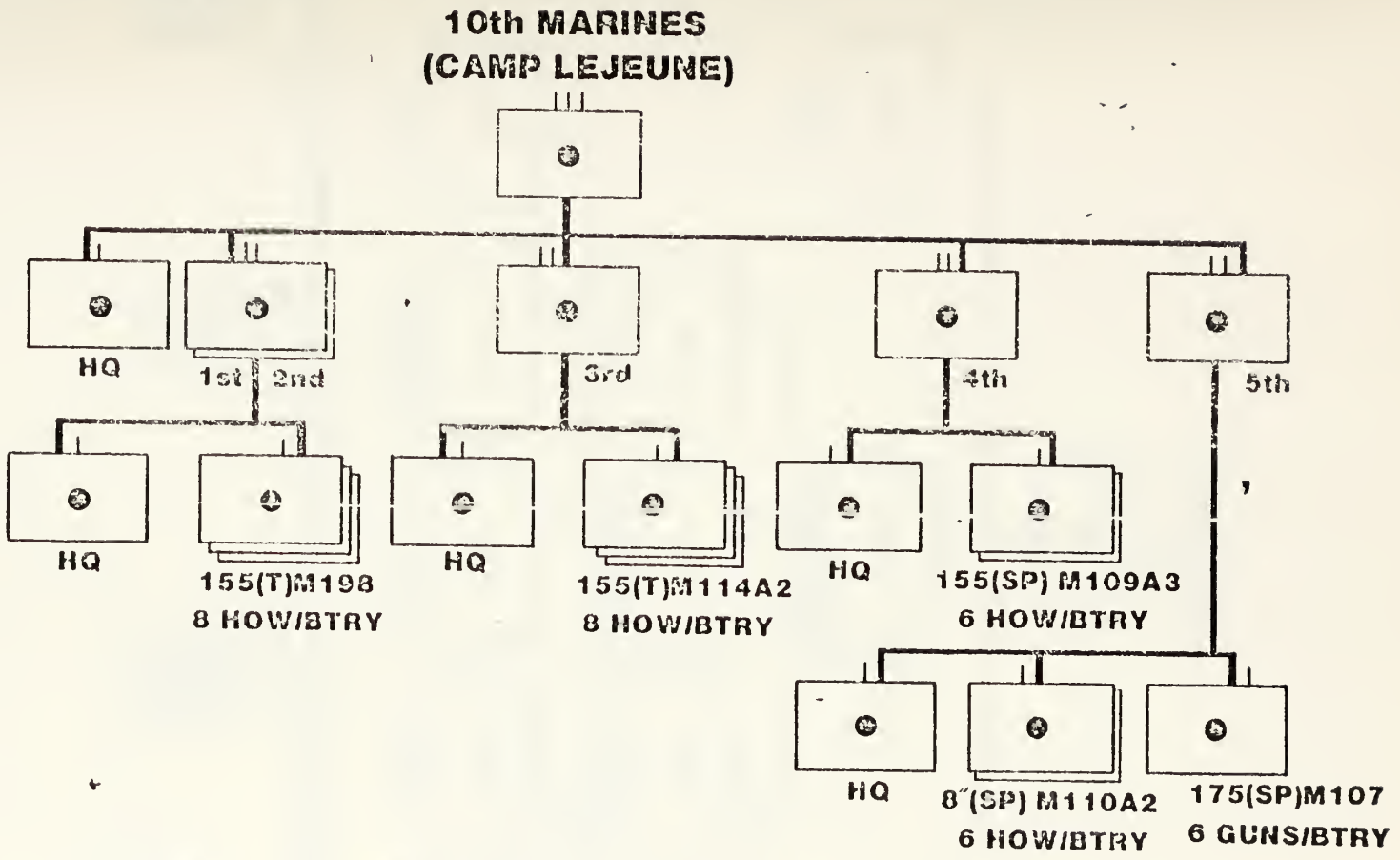
HB	High Burst
HCO	Horizontal Control Operator
HQMC	Headquarters Marine Corps
ICM	Improved Conventional Munition
IMPM	Improved Modified Point Mass
IOC	Initial Operational Capability
IPR	In Progress Review
LDCT	Lightweight Digital Command Terminal
LEAD	Letterkenny Army Depot
LED	Light Emitting Diode
MAGTF	Marine Air Ground Task Force
MAUT	Multi-Attribute Utility Theory
MCCRES	Marine Corps Combat Readiness Evaluation System
MCDEC	Marine Corps Development and Education Command
MDS	Meteorological Data System
MEPGS	Mobile Electric Power Generating Source
MET	Meteorological
MFCC	Mortar Fire Control Calculator
MIFASS	Marine Integrated Fire and Air Support System
MOS	Military Occupational Speciality
MPI	Mean Point of Impact
MPM	Modified Point Mass
MTACCS	Marine Tactical Command and Control Systems
MTBF	Mean Time Between Failure
MTTR	Mean Time To Repair
MV	Muzzle Velocity
MVV	Muzzle Velocity Variation

NAVELEX	Navy Electronics Command
PDU	Power Distribution Unit
PHHC	Programmable Hand-Held Calculator
P3I	Preplanned Product Improvement
RAAM	Remotely Activated Anti-Tank Mine
RAP	Rocket Assisted Projectile
RDP	Range Deflection Protractor
ROC	Required Operational Capability
RPV	Remotely Piloted Vehicle
SAR	Selected Acquisition Report
SCA	Section Chief Assembly
SDR	Signal Data Reproducer
SOP	Standard Operating Procedures
T/O	Table Of Organization
TACFIRE	Tactical Fire Direction System
TDP	Technical Data Package
TFT	Tabular Firing Table
TOF	Time Of Flight
USAFAS	United States Army Field Artillery School
VCO	Vertical Control Operator
VE	Velocity Error
VI	Vertical Interval

APPENDIX B

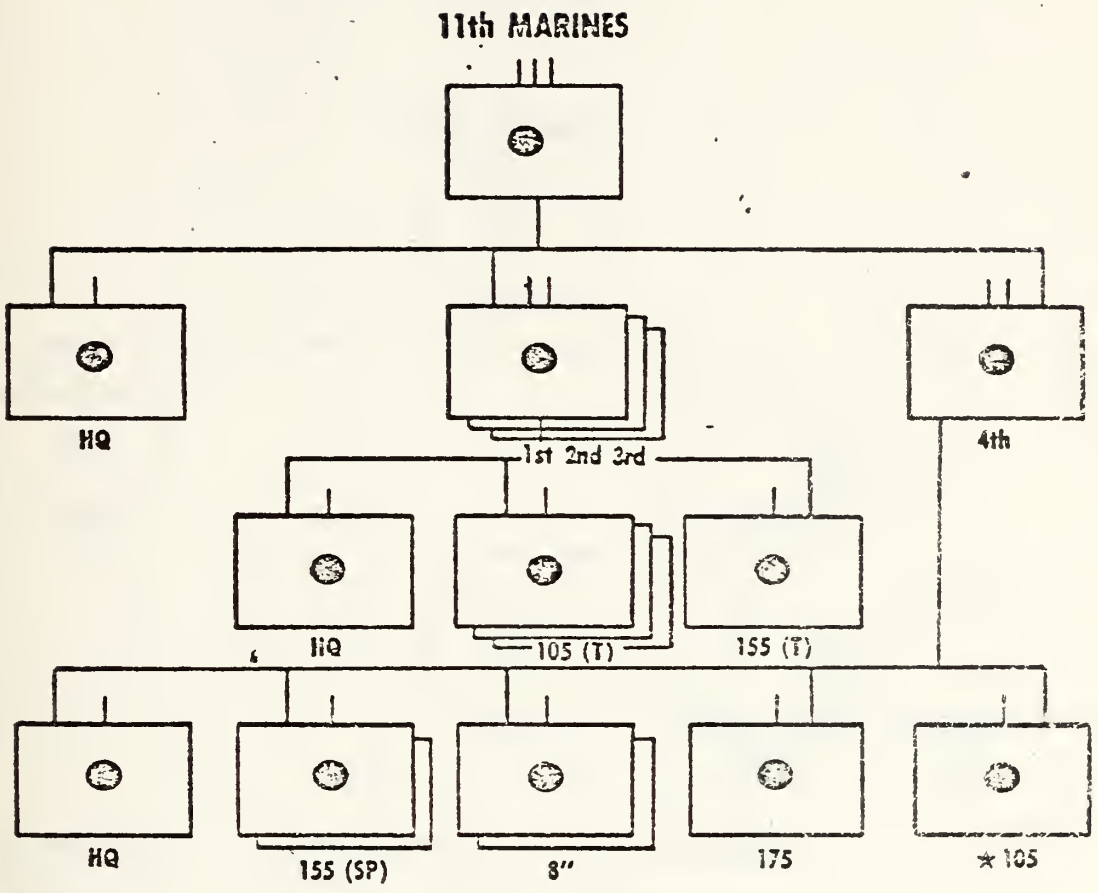
CURRENT FORCE STRUCTURE

This Appendix presents the current force structure of the active and reserve Marine Artillery Regiments. The M198 howitzer is currently being fielded in the 10th Marines. Figure B.2 depicts the changes in structure which will result from the introduction of the M198. The target date for completion of the changes in the structure of the 10th Marines is September 1983. The FY 1987 Projected Force Structure was presented in Chapter Two in Figure 2.1.



1st BN	2nd BN	3rd BN	4th BN	5th BN
HQ	HQ	HQ	HQ	HQ
A 155(T)	D 155(T)	G 155(T)	N 155(SP)	R 8"
B 155(T)	E 155(T)	H 155(T)	O 155(SP)	S 8"
C 155(T)	F 155(T)	I 155(T)		T 175

Figure B.1 10th Marines



1st BN (CAMP PENDLETON)
HQ
A 105 (T)
B 105 (T)
C 105 (T)
K 155 (T)

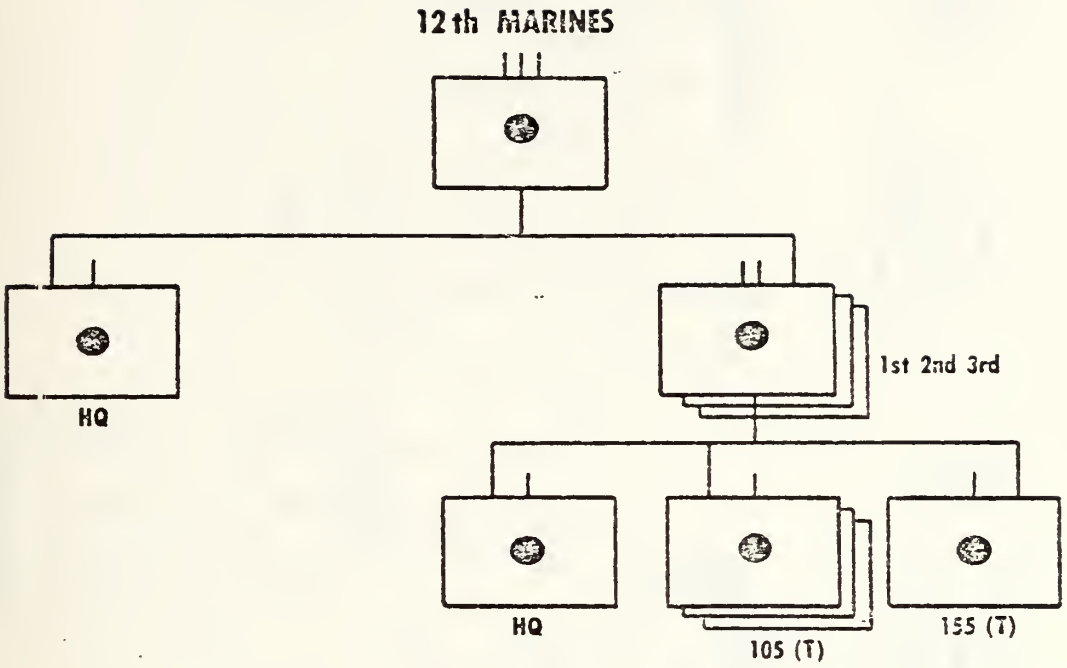
2nd BN (CAMP PENDLETON)
HQ
D 105 (T)
E 105 (T)
F 105 (T)
L 155 (T)

3rd BN (CAMP PENDLETON)
HQ
G 105 (T)
H 105 (T)
I 105 (T)
M 155 (T)

4th BN (29 PALMS)
HQ
1st 155 (SP)
4th 155 (SP)
1st 8"
2nd 8"
3rd 175
★ G/3/12 105 (T)

★ ATTACHED

Figure B.2 11th Marines



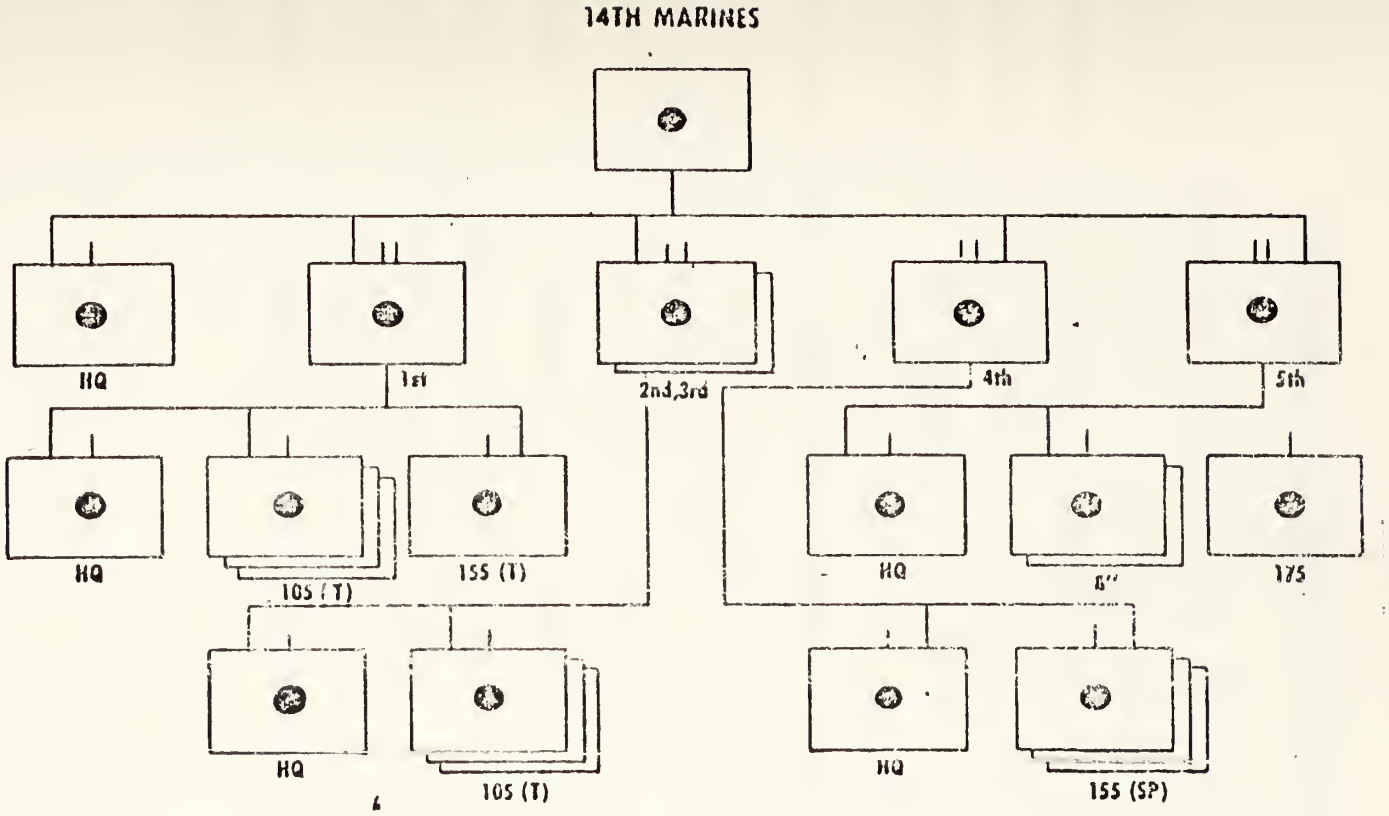
1st BN (HAWAII)
HQ
A 105 (T)
B 105 (T)
C 105 (T)
K 155 (T)

2nd BN (OKINAWA)
HQ
D 105 (T)
E 105 (T)
F 105 (T)
L 155 (T)

3rd BN (OKINAWA)
HQ
★(G 105 (T))
H 105 (T)
I 105 (T)
M 155 (T)
★★1st PLT 8"

★ Attached to 4th BN, 11th MAR
★★ Attached from 1st 8" BTRY, 1st G/S BN, 11th MAR

Figure B.3 12th Marines



1st BN		2nd BN		3rd BN	
HQ LOS ANGELES, CA		HQ DALLAS, TX		HQ PHILADELPHIA, PA	
A SPOKANE, WA	105 (T)	D DALLAS, TX	105 (T)	G W. TRENTON, NJ	105 (T)
B PICO RIVERA, CA	105 (T)	E TEXARKANA, TX	105 (T)	H RICHMOND, VA	105 (T)
C WATERLOO, IA	105 (T)	F JACKSON, MS	105 (T)	I READING, PA	105 (T)
X LOS ANGELES, CA	155 (T)				

4th BN		5th BN	
HQ BIRMINGHAM, AL		HQ SAN FRANCISCO , CA	
K JOLIET , IL	155 (SP)	N EL PASO, TX	8"
L BIRMINGHAM, AL	155 (SP)	O OKLAHOMA CITY,	8"
M CHATTANOOGA, TN	155 (SP)	P DENVER, CO	175

Figure B.4 14th Marines

APPENDIX C

REGIMENTAL COMMANDER'S QUESTIONNAIRE

This Appendix presents the questionnaire which was forwarded to all four artillery Regimental Commanders. The questionnaire consists of multiple choice questions and questions which require a short written response. The questionnaire was designed so that no question splits a typed page. The areas that were originally provided for written comments have been deleted to save space. Specific written comments are addressed in the discussion of the Regimental Commanders' View in Chapter Four. Questions 1 through 11, and questions 19 and 20 address the current status of fire direction. Questions 12 through 18, and questions 21 and 22 address the selection of a new battery level fire direction computer system. The responses of the Regimental Commanders were tabulated and entered on the dashed line preceding the appropriate choice for each question.

REGIMENTAL COMMANDER'S QUESTIONNAIRE

Fire direction is the employment of artillery firepower on the battlefield. It consists of both tactical and technical fire direction. Tactical fire direction involves command, whereas technical fire direction is concerned only with execution. FM 6-40 defines technical fire direction as the conversion of calls for fire from the observer into fire commands to the cannon sections. This questionnaire is concerned with technical fire direction.

1. There has been a continuing debate over whether technical fire direction should be centralized or decentralized. How should technical fire direction in a Direct Support Battalion be exercised?

____Centralized at the Battalion FDC

_4__Decentralized at the Battery FDCs

2. How should technical fire direction in a General Support Battalion be exercised?

_1__Centralized at the Battalion FDC

_3__Decentralized at the Battery FDCs

3. If your answers to questions 1 and 2 differed, please comment on the reasons for the difference.

COMMENTS:_____

4. What is the most common method used to determine firing data in the Battery FDCs of your Regiment?

_1__FADAC

_1__PHHC, TI-59

_2__MANUAL SYSTEM (Chart and GFT)

5. What is the most common method used to determine firing data in the Battalion FDCs of your Regiment?

_2__FADAC

____PHHC, TI-59

_2__MANUAL SYSTEM (Chart and GFT)

6. Has your Regiment experienced difficulty in obtaining repair parts for FADAC?

_3__Yes _1__No

Please comment on the general type of repair parts that have presented the greatest problems.

COMMENTS:_____

7. The following five problem areas have been associated with FADAC. Rank order these problem areas from 1 to 5. Let 1 represent that problem area which has caused the most difficulty for your Regiment.

_1__Level of training of FADAC operators

_5__Level of trainign of Artillery Operations Chiefs

_3__Availability of trained FADAC Repairmen

_4__Repair parts support for FADAC

_2__Maintenance of FADAC generators

Programmable Hand Heli Calculators were procured by the Marine Corps to improve overall FDC operations by augmenting the FADAC and manual chart capabilities. Currently the Fire Controlman (MOS 0844) course at the United States Army Field Artillery School, Fort Sill, allocates 4.2 hours of Gunnery Instruction to the TI-59. The instruction is designed to introduce the student to the TI-59. The Fire Controlman learns how to determine basic firing data using the three methods of target location. The Operations Chief (MOS 0848) course also allocates 4.2 hours of Gunnery Instruction to the TI-59. In addition to the determination of basic firing data the Operations Chief learns how to determine and apply Registration Corrections. Unit training is critical to increasing proficiency with the TI-59.

8. Do you have the resources to adequately train FDC personnel in the operation of the TI-59?

_4__Yes ____No

9. Should Fort Sill allocate additional time for the TI-59?

_4__Yes ____No

10. Which course (if any) should give a higher priority to the TI-59?

____Fire Controlman (MOS 0844)

_2__Operations Chief (MOS 0848)

_2__Both

____Neither

11. In processing a fire mission where does the largest time delay occur?

_1__Transmission of Call for Fire

_3__Actual computation of Firing Data

____Voice Transmission of Fire Commands from FDC to the guns.

Questions 12 to 19 pertain to the selection of a new battery computer system.

12. Rate the importance of fielding a new battery computer system. (Scale One to Five, with Five representing the greatest importance.)

_1__One _2__Two ____Three ____Four _1__Five

The number of responses is printed on the dashed line. Average urgency rating is 2.5

13. Which type of power source would you prefer for a new battery computer system?

____Internal Battery Power

____Standard Marine Corps Mobile Electric Power Generating Source (MEPGS)

_4__Ability to operate from both battery and generator power

14. Rate the importance of including the ability to operate from standard garrison power (60 cycle, 120 volts) in a new battery computer system. (Scale One to Five, with Five representing the greatest importance)

____One _1__Two ____Three _1__Four _2__Five

The number of responses is printed on the dashed line. Average rating is 4.0

15. Should a new battery computer system include the automation of the transmission of Fire Commands to the guns? Note: Firing data would be computed and visually displayed in the FDC. The operator would press a button which would transmit the Fire Commands via radio or wire to an individual gun display unit.

_3__Yes _1__No

16. In selecting a new battery computer system which of the following characteristics should be the most important?

____Size and weight of the system

____Type of power source

____Ease of operation

_4__Reliability

____Maintainability at the organizational/intermediate level

17. Given a "3 X 8" Battalion structure, how should the battery fire direction system be organized?

_1__ 1 Battery FDC equipped with the new battery computer system. Firing data would be transmitted via radio or wire to the firing platoons.

_3__ 2 Platoon FDCs each equipped with the new battery computer system. One of the Platoon FDCs would be designated as the "Primary Battery FDC".

____Other (Please Comment)_____

18. Should the new battery computer system have the capability to perform centralized technical fire direction for all firing batteries in the battalion?

_3__Yes _1__No

19. Given the present fire direction equipment what type of systems improvements can be made to increase the overall effectiveness of fire direction until a new computer system can be fielded?

20. How would you describe the current status of technical fire direction in your regiment?

21. Discuss the impact of the "3 X 8" concept on the fire direction system.

22. What are your recommendations for the design and acquisition of a new battery computer system?

APPENDIX D

BATTALION COMMANDER'S QUESTIONNAIRE

This Appendix presents the questionnaire which was forwarded to all seventeen artillery Battalion Commanders. The questionnaire consists of multipe choice questions and questions which require a short written response. The questionnaire was designed so that no question splits a typed page. The areas that were originally provided for written comments have been deleted to save space. Specific written comments are addressed in the discussion of the Battalion Commanders' View in Chapter Four. Questions 1 through 29, and question 37 address the current status of fire direction. Questions 30 through 36 address the selection of a new battery level fire direction computer system. The responses of the Battalion Commanders were tabulated and entered on the dashed line preceding the appropriate choice for each question.

The final results provide a snapshot of the status of the overall force structure. The five reserve battalions use the Manual System as the primary means of determining firing data. Reserve responses biased the results of some questions relating to FADAC and the PHHC, TI-59. The final results for questions 2, 3, 9, and 15 were biased due to the reserve battalions exclusive use of the manual system. The fact that

the reserve battalions have not really commenced to use the PHHC biased the final results for questions 19, 20, 21, 22, and 27. The reader should note that a significant difference exists between the reserve and active battalions regarding the use of FADAC and the PHHC. Bias has been identified for the reader. In cases where a particular bias was noted, specific comments are provided to explain the tabulated data.

BATTALION QUESTIONNAIRE

Fire direction is the employment of artillery firepower on the battlefield. It consists of both tactical and technical fire direction. This questionnaire is concerned with technical fire direction. FM 6-40 defines technical fire direction as the conversion of calls for fire from the observer into fire commands to the cannon sections. For questions 1 to 4 assume that your Battalion is conducting a FIREX. Headquarters Battery and all the firing batteries are in the field for this exercise.

1. How is technical fire direction exercised?

____Centralized at the Battalion FDC

_16_Decentralized at the Battery FDCs

2. What is the primary method of determining firing data in the Battalion FDC?

_4__FADAC

_3__PHHC, TI-59

_9__MANUAL SYSTEM (Chart and GFT)

ALL five reserve battalions use the manual system. All Marine artillery battalions have a FADAC capability (see question 10).

3. What is the primary method of determing firing data in the Battery FDCs?

_4__FADAC

_4__PHHC, TI-59

_8__MANUAL SYSTEM (Chart and GFT)

The "Manual System" was the response of all five reserve battalions. Not all artillery batteries are authorized a FADAC.

4. If the Battalion FDC receives a Reinforcing mission from the Regimental FDC in which an adjusted grid and altitude are provided, where is the firing data determined?

_3__Battalion FDC _13_Battery FDCs

5. What type of artillery mission would normally be assigned to your Battalion?

_12_Direct Support _4__General Support

6. Does the Battalion have a published Gunnery SOP?

_15_Yes _1__No

7. How old is the Battalion Gunnery SOP (date of latest revision)?

_5__less than 1 year old

_4__1 to 2 years old

_4__2 to 3 years old

_3__more than 3 years old

8. Does the Battalion Gunnery SOP address the structure of an alternate Battalion FDC?

_14_Yes _2__No

9. What is the primary method of determining firing data in the alternate Battalion FDC?

_2__FADAC

_4__PHHC, TI-59

_10_MANUAL SYSTEM (Chart and GFT)

The "Manual System" was the response of all five reserve battalions.

10. Is your Battalion authorized FADAC?

_16_Yes ____No

If your answer to question 10 was "No", skip to question 18.

11. Indicate the number of FADACs that your Battalion is authorized. Additionally indicate how many of these are on hand and how many are operational.

_55_Number Authorized

_54_Number On Hand

_32_Number Operational

Based on this data the operational readiness of FADAC is 59 percent.

12. If any of your FADACs are currently non-operational, what is the average length of time that they have been down?

_3__less than 30 days

_3__30 to 60 days

_1__60 to 90 days

_6__more than 90 days

Thirteen Battaions responded that they had non-operational FADACs. Their responses show the average downtime of the non-operational FADACs. Three of the six FADACS that have been non-operational in excess of ninety days belong to reserve units.

13. Has your Battalion experienced difficulty in obtaining repair parts for FADAC?

_11_Yes _5__No

Please comment on the general type of repair parts that have presented the greatest problem.

COMMENTS:_____

14. Indicate the number of FADAC Repairman (MOS 2885) authorized and the number on hand.

This was not a valid question for the battalion questionnaire, since the current T/Os assign all the FADAC Repairmen to the Regimental Headquarters Battery.

_0__Number Authorized _0__Number On Hand

15. Does your Battalion FDC employ the integrated FADAC/Manual concept to determine firing data?

_9__Yes _7__No

The five reserve battalions responded "No".

16. How would you rate your Battalion FDC's proficiency with FADAC?

____Excellent

_4__Above Average

_5__Average

_3__Below Average

_3__Unsatisfactory

There was a slight bias introduced in Question 16 because the reserve battalions rated their BN FDC's proficiency with FADAC below the average response of the active battalions. All three unsatisfactory responses came from the reserve battalions.

17. The following five problem areas have been associated with FADAC. Rank order these problem areas from 1 to 5. Let 1 represent that problem area which has caused the most difficulty for your Battalion.

_1__Level of training of FADAC operators

_5__Level of training of Artillery Operations Chiefs

_3__Availability of trained FADAC Repairmen

_2__Repair parts support for FADAC

_4__Maintenance of FADAC generators

Ranking was based on total value assigned each alternative by all questionnaires. The alternative with the smallest total was ranked number one.

18. Is your Battalion authorized the PHHC, TI-59?

_16_Yes ____No

If your answer to question 18 was "No", skip to question 28.

Questions 19, 20, 21, 22, and 27 were biased by the fact that the reserve battalions have not really started to use the PHHC, TI-59. However, the final results provide an accurate representation of the total force structure.

19. Indicate how many TI-59s are assigned to the Battalion FDC section and how many of these are operational?

_87_Number assigned to the Battalion FDC

_79_Number operational

Based on the data the operational readiness of the PHHC is 90 percent. All non-operational PHHCs belong to active units.

20. Has your Battalion FDC ever used the TI-59 as the primary method of determining firing data?

_9__Yes _7__No

Four reserve battalions responded "NO".

21. Has your Battalion FDC determined Registration Corrections from a Precision Registration or High Burst Registration with the TI-59?

_8__Yes _8__No

Four reserve battalions responded "No".

22. Has your Battalion FDC worked a Concurrent or Subsequent Met with the TI-59?

_7__Yes _9__No

All Five reserve battalions responded "No".

23. Reliability is defined as the probability that an item will perform its intended function for a specified time interval under stated conditions. How would you rate the reliability of the TI-59?

_6__Excellent

_8__Above Average

_1__Average

_1__Below Average

____Unsatisfactory

No bias was detected. However the reserve responses are based on very limited use of the PHHC.

Currently the Fire Controlman (MOS 0844) course at the United States Army Field Artillery School, Fort Sill, allocates 4.2 hours of Gunnery Instruction to the TI-59. The

instruction is designed to introduce the student to the TI-59. The Fire Controlman learns how to determine basic firing data using the three methods of target location. The Operations Chief (MOS 0848) course also allocates 4.2 hours of Gunnery Instruction to the TI-59. In addition to the determination of basic firing data the Operations Chief learns how to determine and apply Registration Corrections. Unit training is critical to increasing proficiency with the TI-59.

24. Do you have the resources to adequately train FDC personnel in the operation of the TI-59?

_10_Yes _6__No

No Bias was detected.

25. Should Fort Sill allocate additional time for the TI-59?

_16_Yes ____No

26. Which course (if any) should give a higher priority to the TI-59?

_1__Fire Controlman (MOS 0844)

____Operations Chief (MOS 0848)

_15_Both

____Neither

27. How would you rate your Battalion FDC's proficiency with the TI-59?

____Excellent

_4__Above Average

_5__Average

_3__Below Average

_4__Unsatisfactory

Three of the four unsatisfactory responses came from the reserve battalions.

28. In processing a fire mission where does the largest time delay occur?

_2__Transmission of Call for Fire

_7__Actual computation of Firing Data

_7__Voice Transmission of Fire Commands from FDC to the guns.

29. How would you rate the overall state of training of your Battalion FDC?

____Excellent

_6__Above Average

_8__Average

_1__Below Average

_1__Unsatisfactory

Questions 30 to 37 pertain to the selection of a new battery computer system.

30. Rate the importance of fielding a new battery computer system. (Scale One to Five, with Five representing the greatest importance.)

_2__One _2__Two _1__Three _5__Four _6__Five

The number of responses is printed on the dashed line. The average rating is 3.7.

31. Which type of power source would you prefer for a new battery computer system?

_2__Internal Battery Power

____Standard Marine Corps Mobile Electric Power Generating Source (MEPGS)

_14_Ability to operate from both battery and generator power

32. Rate the importance of including the ability to operate from standard garrison power (60 cycle, 120 volts) in a new battery computer system. (Scale One to Five, with Five representing the greatest importance)

_3__One _2__Two _2__Three _5__Four _4__Five

The number of responses is printed on the dashed line. The average rating is 3.3.

33. Should a new battery computer system include the automation of the transmission of Fire Commands to the guns? Note: Firing data would be computed and visually displayed in the FDC. The operator would press a button which would transmit the Fire Commands via radio or wire to an individual gun display unit.

_14_Yes _2__No

34. In selecting a new battery computer system which of the following characteristics should be the most important?

_1__Size and weight of the system

____Type of power source

_4__Ease of operation

_11_Reliability

____Maintainability at the organizational/intermediate level

35. Given a "3 X 8" Battalion structure, how should the battery fire direction system be organized?

_4__ 1 Battery FDC equipped with the new battery computer system. Firing data would be transmitted via radio or wire to the firing platoons.

_12_ 2 Platoon FDCs each equipped with the new battery computer system. One of the Platoon FDCs would be designated as the "Primary Battery FDC".

____Other (Please Comment)_____

36. Should the new battery computer system have the capability to perform centralized technical fire direction for all firing batteries in the battalion?

_13_Yes _3__No

37. Given the present fire direction equipment what type of systems improvements can be made to increase the overall effectiveness of fire direction until a new computer system can be fielded?

ADDITIONAL COMMENTS

A. Status of current technical fire direction system

B. Recommendations for a new battery computer system

DESIGNATOR_____

APPENDIX E

BATTERY COMMANDER'S QUESTIONNAIRE

This Appendix presents the questionnaire which was forwarded to all sixty artillery Battery Commanders. The questionnaire consists of multiple choice questions and questions which require a short written response. The questionnaire was designed so that no question splits a typed page. The areas that were originally provided for written comments have been deleted to save space. Specific written comments are addressed in the Battery Commanders' View in Chapter Four. Questions 1 through 35, and question 43 address the current status of fire direction. Questions 36 through 42 address the selection of a new battery computer system. The responses of the Battery Commanders were tabulated and entered on the dashed line preceding the appropriate choice for each question.

The final results provide an excellent representation of the status of the overall force structure. The vast majority of the fifteen reserve batteries which responded use the Manual System as the primary means of determining firing data. Reserve responses biased the results of some questions relating to FADAC and the PHHC, TI-59. The final results for questions 12, 13, and 17 pertaining to FADAC reflect a bias caused by the reserve batteries exclusive reliance on the

manual system. The fact that the reserve batteries have not really commenced to use the PHHC was reflected in questions 21, 22, 23, 24, 25, 26, 27, 28, and 33. THe final results are biased by the overwhelming negative response from the reserves. The reader should note that a significant difference exists between the reserve and active batteries in regards to the use of FADAC and the PHHC. Bias has been identified for the reader. In cases where a particular bias was noted, specific comments are provided to explain the tabulated data.

BATTERY QUESTIONNAIRE

Fire direction is the employment of artillery firepower on the battlefield. It consists of both tactical and technical fire direction. This questionnaire is concerned with technical fire direction. FM 6-40 defines technical fire direction as the conversion of calls for fire from the observer into fire commands to the cannon sections. For questions 1 to 4 assume that your Battery is participating in a Battalion FIREX. All firing batteries of the Battalion are in the field for this exercise.

1. How is technical fire direction exercised?

_2__Centralized at the Battalion FDC

_41_Decentralized at the Battery FDCs

2. If the Battalion FDC receives a Fire-For-Effect mission and the Battalion FDO decides to Fire-For-Effect with the Battalion, where is the firing data determined?

_5__Battalion FDC _38_Battery FDC

3. If the Battalion FDC receives an Adjust Fire mission from one of your Forward Observers and the Battalion FDO decides to adjust with your unit and Fire-For-Effect with the Battalion, where is the firing data detremined? (Assume good communications exist between your Battery FDC and the FO.)

_4__Battalion FDC _39_Battery FDC

4. If your Battery is a non-adjusting battery in a Battalion Mass mission, where is the firing data determined?

_7__Battalion FDC _36_Battery FDC

Questions 2, 3, and 4 were used as a check on Question 1. If an individual responded "Battalion FDC", then some degree of centralized technical fire direction was being exercised by the Battalion FDC.

5. Does the Battalion have a published Gunnery SOP?

_35_Yes _8__No

6. How old is the Battalion Gunnery SOP (date of latest revision)?

_5__less than 1 year old

_10_1 to 2 years old

_8__2 to 3 years old

_12_more than 3 years old

Generally the Reserve Battalion Gunnery SOP's were older. Fifty percent of the responses from reserve units stated that the SOPs were more than three years old.

7. Does your Battery have a published Gunnery SOP?

_13_Yes _30_No

Seventeen active batteries do not have a published Battery Gunnery SOP. Reserve units did not bias the results.

8. How old is your Battery Gunnery SOP (date of latest revision)?

_5__less than 1 year old

_5__1 to 2 years old

_1__2 to 3 years old

_2__more than 3 years old

9. Given the present methods of determining firing data, how would you like to see technical fire direction exercised?

_1__Centralized at the Battalion FDC

_42_Decentralized at the Battery FDC

10. Indicate which of the following Formal Schools you have completed. Additionally, indicate if you were a resident student or completed the course by correspondence.

_39_Field Artillery Officer Basic Course

_27_Field Artillery Officer Advanced Course

_23_Resident _4__Correspondence

_11_Amphibious Warfare School

_4__Resident _7__Correspondence

11. Identify which weapon system currently applies to your unit.

_21_M101A1 _7__M114A2 _6__M198

_6__M109A2/A3 _3__M110A1/A2 ____M107

12. What is the primary method of determining firing data in your Battery?

_9__FADAC

_10_PHHC, TI-59

_24_MANUAL SYSTEM (Chart and GFT)

Fourteen of fifteen reserve batteries responding answered "Manual System". The responses show that FADAC is not being used at the battery level.

13. Is your Battery authorized a FADAC?

_19_Yes _24_No

Ten of the "No" responses were from reserve units.

If your answer to question 13 was "No", skip to question 20.

14. If your Battery is authorized a FADAC, do you currently have a FADAC on hand?

_15_Yes _4__No

15. (a) Is your FADAC currently operational?

_10_Yes _9__No

Based on this data the operational readiness of FADACs in the firing batteries is 53 percent.

(b) If your FADAC is not operational, how long has it been down?

_2__less than 30 days

____30 to 60 days

_3__60 to 90 days

_4__more than 90 days * (Two of the four belong to the reserves)

16. Have you experienced difficulty in obtaining repair parts for FADAC?

_12_Yes _7__No

Please comment on repair parts that have presented the greatest problems. Identify the item by part name.

COMMENTS:_____

The most common answers were circuit boards, memories, and keyboards.

17. Does your Battery FDC employ the integrated FADAC/Manual concept to determine firing data?

_12_Yes _7__No

Only one reserve unit responded "YES"

18. How would you rate your FDC's proficiency with FADAC?

_1__Excellent

_4__Above Average

_8__Average (No bias was evident in the

_4__Below Average responses.)

_2__Unsatisfactory

19. Which one of the following problem areas normally associated with FADAC has caused the most difficulty for your unit?

_4__Level of training of FADAC operators

_2__Level of Training of Artillery Operations Chief

_10_Maintenance of FADAC

_3__Maintenance of FADAC generators

Three of the four units which answered level of training of FADAC operators were from reserve units.

20. Is your Battery authorized the PHHC, TI-59?

_41_Yes _2__No (Two reserve units)

If your answer to question 20 was "No", skip to question 34.

Questions 21, 22, 23, 24, 25, 26, 27, 28, and 33 were biased by the fact that the reserve batteries have not really started to use the PHHC, TI-59. However, the final results provide an accurate representation of the total force structure.

21. Indicate how many TI-59's you have on hand and how many are operational.

_133_Number On Hand _125_Number Operational

Based on this data the operational readiness of the TI-59 is 94 percent. All of the non-operational PHHC were from active units. The reserves are not really using the PHHC, therefore the results are biased.

22. Has your Battery FDC ever used the TI-59 as the primary method of determining firing data?

_23_Yes _18_No

Eleven of the "No" responses were from reserve units.

23. Has your Battery FDC conducted a Precision Registration using the TI-59?

_27_Yes _14_No

Ten of the "No" responses were from reserve units.

24. Has your Battery FDC conducted a High Burst Registration using the TI-59?

_22_Yes _19_No

Ten of the "No" responses were from reserve units.

25. Has your Battery FDC determined Rregistration Corrections from a Precision Registration or High Burst Registration with the TI-59?

_25_Yes _16_No

Ten of the "No" responses were from reserve units.

26. Has your Battery FDC applied Registration Corrections to the TI-59?

_24_Yes _17_No

Ten of the "No" responses were from reserve units.

27. Has your Battery FDC worked a Concurrent or Subsequent Met with the TI-59?

_18_Yes _23_No

Twelve of the "No" responses were from reserve units.

28. Has your Battery FDC determined Terrain Gun Position Corrections with the TI-59?

_10_Yes _31_No

Thirteen of the "No" responses were from reserve units.

Currently the Fire Controlman (MOS 0844) course at the United States Army Field Artillery School, Fort Sill, allocates 4.2 hours of Gunnery Instruction to the TI-59. The instruction is designed to introduce the student to the

TI-59. The Fire Controlman learns how to determine basic firing data using the three methods of target location. The Operations Chief (MOS 0848) course also allocates 4.2 hours of Gunnery Instruction to the TI-59. In addition to the deteremination of basic firing data the Operations Chief learns how to determine and apply Registration Corrections. Unit training is critical to increasing proficiency with the TI-59.

29. Do you have the resources to adequately train FDC personnel in the operation of the TI-59?

_21_Yes _20_No

30. Should Fort Sill allocate additional time for the TI-59?

_36_Yes _5__No

31. Which course (if any) should give a higher priority to the TI-59?

_4__Fire Controlman (MOS 0844)

_8__Operations Chief (MOS 0848)

_29_Both

____Neither

32. Reliability is defined as the probability that an item will perform its intended function for a specified time interval under stated conditions. How would you rate the reliability of the TI-59?

_10_Excellent

_15_Above Average

_13_Average

_2__Below Average

_1__Unsatisfactory

33. How would you rate your FDC's proficiency with the TI-59?

_7__Excellent

_10_Above Average

_8__Average

_7__Below Average

_9__Unsatisfactory * (All nine were from reserve units.)

34. Based on your experience, where in the processing of a fire mission does the largest time delay occur?

_7__Transmission of the Call for Fire

_21_Actual computation of Firing Data

_15_Voice transmission of Fire Commands from FDC to the guns

Eleven reserve units responded that the actual computation of firing data was where the largest time delay occurs. This is most probably a result of their state of training. The results shown above are therefore biased by the reserve responses.

35. How would you rate the overall state of training of your FDC?

_7__Excellent

_14_Above Average

_18_Average

_4__Below Average

____Unsatisfactory

There was a slight bias introduced because the reserve Batteries tended to rate their FDC's proficiency lower than the average response of the active batteries.

Questions 36 to 43 pertain to the selection of a new battery computer system.

36. Rate the importance of fielding a new battery computer system. (Scale One to Five, with Five representing the greatest importance.)

_2__One _1__Two _11_Three _8__Four _21_Five

The number of responses is printed on the dashed line. The average rating is 4.0.

37. Which type of power source would you prefer for a new battery computer system?

_16_Internal Battery Power

____Standard Marine Corps Mobile Electric Power Generating Source (MEPGS)

_27_Ability to operate from both battery and generator power

38. Rate the importance of including the ability to operate from standard garrison power (60 cycle, 120 volts) in a new battery computer system. (Scale One to Five, with Five representing the greatest importance.)

_4__One _7__Two _5__Three _6__Four _21_Five

The number of responses is printed on the dashed line. The Average rating is 3.9.

39. Should a new battery computer system include the automation of the transmission of Fire Commands to the guns? Note: Firing data would be computed and visually displayed in the FDC. The operator would press a button which would transmit the Fire Commands via radio or wire to an individual gun display unit.

_31_Yes _12_No

40. In selecting a new battery computer system which of the following characteristics should be the most important?

_1__Size and weight of the system

____Type of power source

_10_Ease of operation

_26_Reliability

_6__Maintainability at the organizational/intermediate level

41. Given a "3 X 8" Battalion structure, how should the battery fire direction system be organized?

_9__ 1 Battery FDC equipped with the new battery computer system. Firing data would be transmitted via radio or wire to the firing platoons

_31_ 2 Platoon FDCs each equipped with the new battery computer system. One of the Platoon FDCs would be designated as the "Primary Battery FDC".

_3__Other (Please Comment)_____

42. Should the new battery computer system have the capability to perform centralized technical fire direction for all firing batteries in the Battalion?

_38_Yes _5__No

43. Given the present fire direction equipment what type of systems improvements can be made to increase the overall effectiveness of fire direction until a new computer system can be fielded?

ADDITIONAL COMMENTS

A. Status of current technical fire direction system

B. Recommendations for a new battery computer system

DESIGNATOR_____

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